# Acoustic Assessment of Bats near the Landusky Wind Turbine Site in the Little Rocky Mountains of North Central Montana and Management Recommendations for Bats

Prepared for:

Environmental Management Bureau of the Permitting and Compliance Division
Montana Department of Environmental Quality
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**Montana Natural Heritage Program**
a cooperative program of the
Montana State Library and the University of Montana


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Agreement Number:

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# EXECUTIVE SUMMARY

Montana's bat populations face a wide array of conservation issues, including loss of roosting sites, elimination of prey species, collision or drowning hazards at sites where they forage, drink, and mate, and a lack of baseline information on distribution and habitat use that is available to resource managers. In recent years, concerns have focused on fatalities at wind turbine facilities and those resulting from White-nose Syndrome (WNS). Bat fatalities are widespread at wind energy facilities across the United States with 600,000 to 888,000 fatalities estimated in 2012 alone. Wind energy caused fatalities may be having significant impacts on bat populations because bats are long-lived and have only one or two young per year. Given these concerns, plans to install a 225-kilowatt wind turbine at the Landusky mine site, and the proximity of Montana's largest known bat hibernacula at Azure Cave, the Montana Department of Environmental Quality (DEQ) requested evaluation of bat activity in the area of the turbine in order to assess risks and provide recommendations for mitigating potential long-term impacts to bats. This was the first ultrasonic acoustic detector installed in what has grown to become a regional network of detectors deployed over multiple years to document activity patterns of bats across Montana, northern Idaho, and the western Dakotas.

The overarching objectives at Landusky were to inform wind turbine management by documenting baseline information on: (1) bat species composition and activity levels in the vicinity of the Landusky wind turbine site for approximately one year prior to and two years post turbine installation; (2) timing of species immergence to and emergence from hibernacula for non-migratory bat species; (3) timing of migrations by tree roosting migratory species that have been documented as having the highest levels of mortality from collisions with wind turbines; and (4) correlates of bat activity such as wind speed, temperature, precipitation, barometric pressure, and moon illumination.

We recorded bat echolocation calls from sunset to sunrise nightly with an SM2Bat detector/recorder at the Landusky Mine water treatment ponds between 28 September 2011 and 5 August 2014 and with an SM2Bat+ detector/recorder near the base of the Landusky Mine wind turbine between 12 October 2012 and 29 September 2014. A total of 111,353 and 937 bat call sequences were recorded, with 12.9 and 22.5 percent being auto-identified to species by Sonobat 3.0 or Kaleidoscope Pro 2.0 software, at the water treatment pond and wind turbine sites, respectively. Of these, 2,905 and 249 call sequences were fully reviewed by hand at the water treatment ponds and wind turbine sites, respectively.

Ten species were definitively confirmed by hand review using the bat call characteristic identification guidelines in Montana's Bat and White-Nose Syndrome Surveillance Plan and Protocols: Townsend's Big-eared Bat (*Corynorhinus townsendii*), Big Brown Bat (*Eptesicus fuscus*), Spotted Bat (*Euderma maculatum*), Eastern Red Bat (*Lasiurus borealis*), Hoary Bat (*Lasiurus cinereus*), Silver-

haired Bat (*Lasionycteris noctivagans*), Western Small-footed Myotis (*Myotis ciliolabrum*), Long-eared Myotis (*Myotis evotis*), Little Brown Myotis (*Myotis lucifugus*), and Long-legged Myotis (*Myotis volans*). Call sequences recorded and reviewed during this study did not have definitive characteristics necessary to confirm the presence of Fringed Myotis (*Myotis thysanodes*), but this species should be regarded as potentially present in the region. This is the first study to document the presence of Spotted Bat and Eastern Red Bat in the region of the Little Rocky Mountains and we documented the ten species definitively detected in 33 monthly time periods with no previous documentation of their presence in the region.

Patterns of bat activity observed at the Landusky water treatment ponds and wind turbine site are generally consistent with other sites across the regional network of acoustic detectors that have been deployed between 2012 and 2015. Bat activity was documented year round at the water treatment facility ponds with only Big Brown Bat definitively identified between December and March; a small amount of unidentified Myotis activity was also documented during this time period. Bat activity near the base of the wind turbine was basically limited to May through September, but single passes of an unidentified 30 kHz bat were recorded on 25 October 2013 and 17 November 2012.

Bat activity at the water treatment ponds began to increase each year in mid to late April, increased to an average of 576 to 889 bat passes per night in July, August, and September in 2012 and 2014, and then was greatly reduced after late September. Winter activity from November through March was 2-3 orders of magnitude lower than activity during the active season and was relatively constant across the entire study period with a typical average of 0.5 to 10 bat passes per night during most weeks when the detector was functioning. Bat activity near the base of the wind turbine was 2 orders of magnitude less than at the water treatment ponds during the active season, didn't begin until early May, and essentially ceased by mid to late September.

During the active season (April to October), bat activity occurred throughout the night, but often exhibited bimodal pulses at one to two hours after sunset and five to nine hours after sunset. During the inactive season (November to April), there were no clear patterns in timing of activity at the water treatment ponds.

Average nightly bat pass temperatures during the warmer months closely approximated average background temperatures indicating that bats were active during most temperatures that were available. However, during cooler months, average and minimum bat pass temperatures were up to 11 °C and 22 °C warmer than average nightly background temperatures, respectively. The average nightly bat pass temperatures usually did not go below 3 to 4 °C, indicating that bats restricted their activity during cooler months to warmer time periods. The minimum nightly average for bat pass temperatures was 1.3 °C for 10 bat passes in January of 2013. The minimum bat pass temperatures recorded for individual species were often higher than have been recorded on other detectors across the region, possibly indicating that roost sites for most species are somewhat distant from the detector locations and that bats may not be flying far from their

roost sites during colder weather conditions in this relatively harsh landscape.

Bat activity patterns in relation to wind speed for the nearby Zortman and Hays weather stations and the anemometer on the turbine nacelle indicate that bats are more active at wind speeds of 6 meters per second or less than would be expected if bat activity was randomly distributed across all wind speeds available to them. This pattern was most clear in association with wind data from the Zortman weather station where approximately 85% of bat passes at both the water treatment ponds and wind turbine detectors were associated with wind speeds of 2 meters per second or less and bat activity was much greater in the 0 and 1 meter per second wind speed classes than would be expected at random. Furthermore, only a tiny fraction of activity was associated with wind speeds of 5 meters per second or more. Patterns of bat activity in association with the wind data from the Hays weather station and the turbine nacelle more closely matched background wind patterns. However, bat activity was typically greater than what would be expected if activity was randomly distributed across available wind speeds for wind speeds of 6 meters per second or less for both of these sites as well. These patterns of restricted bat activity at higher wind speeds hold across the entire detector network where, overall, bat activity was greater than expected at random for wind speeds less than 3 meters per second and wind speeds less than 6 meters per second accounted for 95 percent of bat passes.

Most, 80 and 85 percent, of bat activity at the water treatment and wind turbine sites, respectively, was associated with little to no change (-1 to +1 millibars change per hour) in hourly barometric pressure and bat activity in these pressure change classes was much greater than would be expected if bat activity were randomly distributed across background pressure change classes that were recorded. Across the detector network, 77 percent of bat activity was associated with little to no change (-1 to +1 millibars) in hourly barometric pressure. However, bat activity was greater than expected during negative changes (-1 to -3 millibars) in hourly barometric pressure and was less than expected with neutral or positive changes (1 to 2 millibars) in hourly barometric pressure than if it were randomly distributed across background pressure change classes.

While the magnitude of the effect is small, bat activity at both the water treatment ponds and wind turbine site was greater during hours without precipitation than would be expected if bat activity was randomly distributed between hours with and without precipitation. This same small magnitude pattern of greater bat activity than expected at random during hours without precipitation was evident across the entire detector network.

In a very clear trend, bat activity, as measured by the percentage of hours with bat passes, at the water treatment ponds was progressively greater than would be expected at random during moon illumination levels below 0.6 and progressively lower than would be expected at random during moon illumination levels above 0.6. Bat activity levels were generally higher than would be expected at random at lower moon illumination levels and lower than would be expected at random at higher moon illumination levels at the wind turbine site as well. However, the trend was not progressive

and was not as clear, probably as a result of the overall low volume of bat passes recorded over nearly two years of detector deployment at the wind turbine.

Identification of individual species activity patterns in this study was hindered by relatively low and potentially inconsistent rates of auto-identification of call sequences to species at both the water treatment ponds and wind turbine detectors. Thus, activity patterns for species from auto-identified call sequences should be regarded as speculative due to a variety of issues that might cause auto-identifications to be inaccurate and/or inconsistent.

Of the six species for which there is at least some justification for showing potential patterns of documented activity from auto-identified call sequences, there were several patterns of general interest. First, activity levels at the water treatment ponds were one to two orders of magnitude higher at the water treatment ponds than at the wind turbine. Second, with the exception of 2013, activity levels generally were low in April and May, rose in June, peaked in July, and then tapered off between late September and early November to no passes at the wind turbine and exceedingly low numbers of passes at the water treatment ponds throughout the winter months. Third, while Hoary Bat activity was relatively low compared to other species at the water treatment ponds, it had among the highest average number of nightly passes per week at the wind turbine during June and July. The Landusky wind turbine may thus pose a relatively higher risk to this species as compared to others, especially when considering the higher mortality rates documented at wind turbine facilities.

The above measures of overall bat activity near detectors, hand confirmed presence of individual species by month, and hand confirmed minimum temperatures associated with bat passes of individual species are all stable metrics upon which management recommendations can be made. However, patterns of activity of individual species resulting from automated analyses should be used with a great deal of caution due to low rates of species assignment and low or uncertain rates of accuracy of those assignments. Furthermore, while bat activity near the base of the turbine was minimal and generally limited to May through September, it should be noted that bat activity at the height of the turbine's nacelle was not monitored during this study and activity of high flying bats (e.g., Eastern Red Bat, Hoary Bat, and Silver-haired Bat, the three species that have suffered approximately 75% of the documented mortalities associated with wind turbines across North America) in the vicinity of the blades may not have been recorded. Thus, the following management recommendations avoid use of activity patterns of individual species as determined by automated analyses and instead rely on results of hand confirmed analyses, general patterns of bat activity that were recorded at the study site, and results of published studies of wind turbine impacts on bat species.

Management recommendations for the Landusky wind turbine and habitats across the Landusky Mine site include: (1) setting the turbine cut-in speed to $\geq$ 6.0 m/sec between April and October to align with newly adopted

American Wind Energy Association standards – especially important in July, August, September, and October during periods of peak bat activity and when migratory species are passing through and local bats are swarming and breeding; (2) maintaining grassland habitats near the base of the detector to avoid attraction of bats to potential tree roost sites or insects; (3) avoiding creation of pond habitats on the ridge that the wind turbine is on and, when and where possible, eliminate pond habitats near the turbine (e.g., holding ponds near road due south of the detector) to avoid attraction of bats to drinking areas; (4) protecting potential natural roost sites away from the turbine by conserving large diameter trees (especially snags with loose bark), rock outcrops, and cliff crevices; (5) maintaining accessibility of underground mine entrances that bats may be using as summer or winter roosts; and (6) installing bat houses on warm south and west facing walls of mine buildings that are distant from the turbine to provide summer roosting habitat and avoid bat use of internal portions of mine buildings.

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# INTRODUCTION

Montana's bat populations face a wide array of conservation issues, including loss of roosting sites, elimination of prey species, collision or drowning hazards at sites where they forage, drink, and mate, and a lack of baseline information on distribution and habitat use that is available to resource managers. In recent years, concerns have focused on fatalities at wind turbine facilities and those resulting from White-nose Syndrome (WNS) (Table 1). The large increases in mortality posed by these threats are especially significant to bat populations because bats are long-lived and have only 1 or 2 young per year (Barclay and Harder 2003).

## WIND TURBINE IMPACTS

Bat fatalities are widespread at wind energy facilities across the United States with 600,000 to 888,000 fatalities estimated in 2012 alone (Hayes 2013, Smallwood 2013). The widespread nature of these fatalities coupled with low fecundities of bats raise concerns that wind turbines may be having significant impacts on bat populations (Barclay and Harder 2003, Kunz et al. 2007, Arnett et al. 2008). Of North America's 45 documented bat species, mortalities from wind turbines have been documented in 11 and 6 of them potentially occur in the Little Rocky Mountains for at least a portion of the year (Tables 1 and 2; Kunz et al. 2007, Arnett et al. 2008). Of these species, mortality rates have been highest (≥ 75% of mortalities) in tree roosting migratory species such as the Eastern Red Bat (*Lasiurus borealis*), Hoary Bat (Lasiurus cinereus), and Silver-haired Bat (*Lasionycteris noctivagans*) (Kunz et al. 2007, Arnett et al. 2008, Arnett et al. 2011). Thus, the majority of mortalities at the Landusky wind turbine site would be expected to be associated with these three migratory species during migratory events. However, resident bats may also be impacted (Poulton and Erickson 2010) and impacts may occur even during the winter. For example, passive acoustic monitoring data from Canada suggests that non-migratory overwintering bats may remain active to some degree when temperatures go down to as low as -6 or -7 °C (21 to 19 °F) (Lausen and Barclay 2006).

## WHITE-NOSE SYNDROME IMPACTS

Since 2006, White-Nose Syndrome, resulting from the cold adapted fungus *Pseudogymnoascus destructans*, has killed an estimated 5.7 to 6.7 million bats in eastern North America (Blehert et al. 2008, Lorch et al. 2011, USFWS News Release January 17, 2012, Minnis and Lindner 2013). As a result, the extinction of Little Brown Myotis (*Myotis lucifugus*) is predicted in eastern North America by 2026 (Frick et al. 2010), Little Brown Myotis, Northern Myotis (*M. septentrionalis*), and Tri-colored Bat (*Perimyotis subflavus*) were emergency listed as Endangered under Canada's Species at Risk Act (COSEWIC 2012), Little Brown Myotis has been petitioned for emergency listing under the United States Endangered Species Act (Kunz and Reichard 2010), and Northern Myotis has been listed as Threatened under the United States Endangered Species Act across its range, including nine eastern Montana counties (USFWS 2015). *P. destructans* has progressed westward to states along the Mississippi River corridor as well as the Province of Ontario, Canada, has caused WNS in at least three species documented in Montana, has been detected in other species that may serve as local or regional vectors, and seems likely to

affect other Montana species due to the close relatedness of species that have been impacted (Table 1, Blehert et al. 2011, Heffernan 2014).

## Acoustic Monitoring Network

Starting in the fall of 2011, various federal, state, and tribal partners began deploying SM2Bat, SM2Bat+, and SM3Bat ultrasonic detectors to gather year-round baseline information on bat activity in various localities across Montana. During 2012, individual efforts began to coalesce into a regional network of detectors to address most bat species known to occur in Montana (Figure 1, Table 1, Maxell 2015). Most of the recordings from this array are being processed, analyzed, and archived at the Montana Natural Heritage Program.

## Project Need

The Montana Department of Environmental Quality (DEQ) installed a GWL 225 kilowatt Global Wind Power wind turbine at the Landusky mine site (Latitude = 47.9090, Longitude = -108.6195) on 29 October 2012 in order to provide ongoing renewable power for water treatment of mine effluent (Figures 2-4). Given potential impacts to bats, year-round evaluation of bat activity in the area of the turbine was initiated prior to turbine installation on 28 September 2011. The major goals of this effort were to assess bat activity for approximately one year prior to turbine installation and 2 years after installation in order to gather information that might allow for long-term mitigation of potential impacts to bats from turbine operation.

## Species Potentially Present

Of Montana's 15 known bat species, 8 had been documented in the vicinity of the Little Rocky Mountains prior to 2011 and 3 more had the potential to occur there during a portion of the year (Table 2). Of these 11 species, Townsend's Big-eared Bat (*Corynorhinus townsendii*), Big Brown Bat (*Eptesicus fuscus*), Western Small-footed Myotis (*Myotis ciliolabrum*), Little Brown Myotis, and Long-legged Myotis (*Myotis volans*), have been documented overwintering in Azure Cave which is located just 3.6 km to the east of the turbine site and is Montana's largest known bat hibernaculum with estimated winter roost populations of approximately 1,750 bats in 1998, 2014, and 2015 (Figure 2a, Hendricks 1998, Hendricks et al. 1999, Maxell et al. 2014, Maxell et al. 2015). Prior to this study, Long-eared Myotis (*Myotis evotis*), was recognized as potentially overwintering in the area and Spotted Bat (*Euderma maculatum*), Eastern Red Bat, Hoary Bat, Silver-haired Bat, and Fringed Myotis (*Myotis thysanodes*) were generally believed to be solely migratory (Table 2).

## Objectives

The objective of this project was to provide management recommendations for long-term mitigation of wind turbine and other impacts to bats by documenting baseline information on: (1) bat species composition and activity levels in the vicinity of the Landusky wind turbine site for approximately one year prior to turbine installation and approximately 2 years post turbine installation; (2) timing of species immergence to and emergence from hibernacula for non-migratory bat species; (3) timing of migrations by tree roosting migratory species that have been documented as having the highest levels of mortality from collisions with wind turbines; and (4) correlates of bat activity such as wind speed, temperature, precipitation, barometric pressure, and moon illumination.

# METHODS

## INITIAL SITE EVALUATION

On the afternoon of 28 September 2011, B. Maxell met with Mike Flatt from Spectrum Engineering and discussed prevailing weather and wind patterns, potential sources of ultrasonic noises, the proposed location of the wind turbine, and characteristics of water sources (e.g., pH, openness during the winter, exposure to wind, proximity to limestone outcrops) around the Landusky mine site. B. Maxell subsequently visited several localities around the mine site during windy conditions on the evening and night of 28 September 2011 in order to evaluate wind exposure, environmental sources of ultrasonic noise with a Pettersson D240x ultrasonic detector, and the landscape context of various ponds. These evaluations identified two locations that were likely to have relatively high bat activity and good recording conditions near the turbine because they are protected from the wind and are near water bodies where bats are likely to drink: (1) the northern edge of the southeast most retaining pond (Latitude = 47.90592, Longitude = -108.61878); and (2) the northern edge of the rainwater pond just to the east of the southwestern treatment building (Latitude = 47.90597, Longitude = -108.62655) (Figures 2b and 3a-d). Locations on the highest ridge above, and to the east of, the main mine office building were deemed too windy for placement of a detector (i.e. there would have been a huge amount of wind-generated noise files to filter through and the microphone and other portions of the detector were likely to be damaged by high winds). Although locations on the ridge near the wind turbine site would allow documentation of bat activity at the actual wind turbine, they were initially deemed less suitable for documenting bat activity in the general area because of higher winds and a lack of water for bats to drink.

## BAT DETECTOR DEPLOYMENT

The location near the water treatment building was chosen for initial long-term deployment of a bat detector because it was more sheltered from the wind, was adjacent to two water bodies that might attract bats, and had open water during the winter. Just before dark on the evening of 28 September 2011 a Song Meter SM2Bat detector/recorder (Wildlife Acoustics Inc., Maynard, MA) was deployed on the northern edge of the rainwater pond approximately 400-meters southwest of the proposed wind turbine location (Table 3, Figures 2b, 3a, and 3c). On 4 November 2011, a second microphone on the same detector/recorder was subsequently deployed 20-meters northeast of the northeast corner of the water treatment pond and the solar panel, battery, and detector/recorder was moved to 50-meters north of the rainwater pond in order to provide better solar exposure (Table 2, Figures 2b and 3a-d). On 28 January 2012, a second solar panel was installed to ensure that the battery powering the detector/recorder was always fully charged. Overall, this detector was fully operational for a total of 815 nights and 9,361 hours between 28 September 2011 and 29 September 2014 (Table 3).

A second detector/recorder, a Song Meter SM2Bat+ (Wildlife Acoustics Inc., Maynard, MA), became available for deployment at the Landusky site and was installed approximately 75-meters south of the wind turbine location on

12 October 2012; 17 days before the installation of the wind turbine (Table 2, Figures 2b and 4). Overall, this detector was fully operational for a total of 717 nights and 8,406 hours between 12 October 2012 and 29 September 2014 (Table 3).

The SM2Bat (water treatment ponds) and SM2Bat+ (wind turbine ridge) ultrasonic detector/recorders were deployed, monitored, and maintained with the equipment, supplies, settings, and protocols listed in Montana's Bat and White-Nose Syndrome Surveillance Plan and Protocols 2012-2016 (Maxell 2015).

A variety of factors influence the detection of a bat echolocation call and the quality of the resulting recording. These include sensitivity of the individual microphone, temperature, humidity, wind speed, and frequency, amplitude, distance, and directionality of echolocation calls emitted by bats (Parsons and Szewczak 2009, Agranat 2014). The energy of sounds spreading in all directions diminishes by one fourth for every doubling of distance because the surface area of a sphere is related to the square of its radius. Furthermore, higher frequency sounds are diminished over shorter distances because of atmospheric absorption (Parsons and Szewczak 2009, Agranat 2014). Testing of the SMX-US microphones used in this study indicates that bats emitting frequencies in the range of 20 kHz should be detected at distances of 24 to 33 meters from the microphone while those emitting frequencies in the range of 40 kHz should be detected at distances of 18 to 22 meters (Agranat 2014). These distances are the radii of the relevant spheres of detection around microphones when they are at full sensitivity. However, we know that sensitivity varied over time as a result of precipitation and freezing events, some of which permanently reduced the sensitivity of microphones so that they required replacement (Table 3).

## Data Management & Call Analyses

Acoustic file recordings, in both original WAC and processed WAV formats, are stored in the Montana Bat Call Library which is housed on a series of 15-20 Terabyte Drobo 5D and 5N storage arrays at the Montana State Library as well as a secondary offsite location to protect against catastrophic loss. Acoustic analysis results, temperature files, weather station data, and solar and lunar data were all processed and combined within SQL database tables in accordance with the general work flow pattern for data management and analysis outlined in the text and in Appendices 8-10 of Maxell (2015). Bat call sequences were analyzed with the goal of definitively identifying individual species presence by month and individual species' minimum temperatures of activity in accordance with the Echolocation Call Characteristics of Montana Bats and Montana Bat Call Identification materials in Appendices 6 and 7 of Montana's Bat and White-Nose Syndrome Surveillance Plan and Protocols 2012-2016 (Maxell 2015).

## Weather Station Data

Weather station data were downloaded using the Mesowest application programming interface as outlined in Appendix 9 of Maxell (2015). Wind speed and direction, precipitation, and temperature data were downloaded from both the Zortman Mine weather station (47.92128, -108.55114) which is located 5.4 and 5.9 kilometers east northeast of the turbine and water treatment ponds detectors, respectively and the Hays Site MT-66 MP 10.5 weather station (47.91928, -108.72611) which is located 8.0 and 7.6

kilometers east of the turbine and water treatment ponds detectors, respectively. Wind speed data from the Zortman weather station was available for 99.8% and 99.7% of the hours of detector deployment at the water treatment ponds and turbine detectors, respectively. Wind speed data from the Hays weather station was available for 75.7% and 79.7% of the hours of detector deployment at the water treatment pond and turbine detectors, respectively.

In addition to wind speed and direction data available from these weather stations, wind speed and direction data for an anemometer on the wind turbine ridgeline deployed between 9 November 2005 and 22 August 2010 and wind speed data from an anemometer on the nacelle of the wind turbine from November of 2011 to September of 2014 was also available. It is important to note that none of these anemometer readings are likely to precisely represent wind speeds bats recorded at the detectors experienced due to the lengthy distances between the detectors and the Zortman and Hays weather stations and the heights of the anemometers on the wind turbine ridgeline relative to likely heights of detection at the detectors.

Although temperature data was available directly from the bat detectors/recorders, we also downloaded temperature data from the Zortman weather station. Temperature data was available for 99.8% and 99.7% of the hours of detector deployment at the water treatment pond and turbine detectors, respectively.

Barometric pressure data was downloaded from the Malta Airport weather station (48.36694, -107.91934) which is located 55.3 and 55.9 kilometers northeast of the turbine and water treatment pond detectors, respectively. Barometric pressure data was available for 98.8% and 98.0% of the hours of detector deployment at the water treatment pond and turbine detectors, respectively.

## Solar and Lunar Data

Solar and lunar data were calculated for all hours of detector deployment using the Python package ephem (3.7.6.0), which uses well-established numeric routines to produce high-precision astronomy computations (see Appendix 10 of Maxell 2015). The underlying code produces results nearly identical to data available from the U.S. Naval Observatory (Astronomical Applications Department). Precise times for sunrise, sunset, moonrise, moonset, and percent illumination were calculated for each detector site based on latitude, longitude, and date. It should be noted that local topography is not incorporated into any of these calculations. Therefore, the exact timing of these events on the ground may differ slightly from those produced by this model, but should typically be within a few minutes unless local terrain differs greatly from the modeled horizon (e.g. if the site is at the bottom of a canyon).

# Results

## Total Volume of Bat Passes and Auto-Identification Rates

Between 28 September 2011 and 5 August 2014, a total of 111,353 bat call sequences were recorded, with 12.9 percent (monthly range 0.0 to 50.0 percent) auto-identified to species by Sonobat 3.0 or Kaleidoscope Pro 2.0 software, at the water treatment pond (Table 4, Figure 5). Overall rates of auto-identification at the water treatment ponds were significantly lower than the regional network average of 23.7 percent. However, auto-identification rates during a good portion of the study approximated the network average (Table 4, Figure 5). The overall low auto-identification rates are probably largely a result of a decline in sensitivity of microphones after rain events and the fact that the left microphone was near the water treatment facility and was subject to a variety of extraneous noises as well as bats using approach-phase calls a relatively higher percentage of the time in the presence of the building (Tables 3 and 4, Figure 5, Maxell 2015). The SM2Bat detector/recorder also completely failed after some cold weather and rain events (Table 3) and it is possible that some good recording periods with ideal weather conditions that would have yielded relatively high auto-identification rates were missed as a result.

Between 12 October 2012 and 29 September 2014, a total of 937 bat call sequences were recorded, with 22.5 percent (monthly range 0.0 to 100 percent) auto-identified to species at the wind turbine (Table 5, Figure 5). Auto-identification rates at the wind turbine were extremely low (1.2 percent) in 2013 despite the fact that the detector was fully operational, but approximated the regional network average of 23.7 percent between June and September of 2014 (Table 5, Figure 5). The low auto-identification rates in 2013, are likely a somewhat anomalous result of a relatively small number of bat passes being recorded during the active season of 2013 relative to 2014 (Table 5).

## Species Present & Activity Periods

Of the call sequences auto-identified to species, 2,905 and 249 were fully reviewed by hand at the water treatment ponds and wind turbine sites, respectively. Of the 214 months with calls auto-identified to thirteen different species, 116 months (54 percent) were confirmed by hand review for ten species (Table 6). Big Brown Bat, Spotted Bat, Hoary Bat, Silver-haired Bat, Western Small-footed Myotis, Long-eared Myotis, and Little Brown Myotis had relatively high rates of monthly hand confirmation (65.0 to 100 percent), while Townsend's Big-eared Bat, Eastern Red Bat, and Long-legged Myotis had relatively low rates of monthly hand confirmation (5.6 to 15.4 percent) (Table 6). Despite having auto-identified call sequences and theoretically being potentially present in the region, Pallid Bat, Northern Myotis, and Fringed Myotis were not hand confirmed (Table 6). Of these species, Fringed Myotis is the only species we believe should be regarded as potentially present in the Little Rocky Mountains because it has been previously captured on the Missouri River approximately 60 km to the west-southwest in 2003 (Tables 2 and 6, MTNHP 2015).

This is the first study to document the presence of Spotted Bat and Eastern Red Bat in the region of the Little Rocky Mountains and we documented the ten species definitively detected in 33 monthly time periods with no

previous documentation of their presence in the region (Tables 7-9). Ten species were definitively confirmed by hand review at the water treatment ponds with 31 months of newly documented activity, including a seven month expansion to year-round activity by Big Brown Bat, a five-month expansion for Silver-haired Bat, four-month expansions for both Hoary Bat and Western Small-footed Myotis, and a three-month expansion for Long-eared Myotis (Table 7). Eight species were definitively confirmed by hand review at the wind turbine with two additional months of newly documented activity, including the confirmation of activity by Long-legged Myotis in May and Eastern Red Bat in September (Table 8).

As compared to the regional network of acoustic detectors, most of the species confirmed at the Landusky water treatment pond and wind turbine sites had reduced (one to six months) periods of confirmed activity (Table 9). With the exception of Big Brown Bat, which was confirmed present in every month of the year, species at the Landusky sites were typically not confirmed during the relatively colder time periods that they have been confirmed elsewhere in the network (Table 9). For some species, this likely indicates that their overwintering sites are somewhat distant from the locations of the acoustic monitoring stations and that the species are probably only present at the detector locations during a portion of the year (e.g., Silver-haired Bat and Little Brown Myotis). For Spotted Bat and Eastern Red Bat, which are both long distance migrants, this may indicate that the Little Rockies are used for only a portion of the active season each year, perhaps by only one sex or by certain age classes. For others, it likely indicates a simple failure to record definitive call characteristics (e.g. Townsend's Big-eared Bat and Western Small-footed Myotis).

## General Patterns of Bat Activity

Bat activity was documented year round at the water treatment facility ponds with only Big Brown Bat definitively identified between December and March; a small amount of unidentified Myotis activity was also documented during this time period (Tables 7 & 10, Figures 6a & 7). Bat activity at the water treatment ponds began to increase each year in mid to late April. It increased to an average of 576 to 889 bat passes per night in July, August, and September in 2012 and 2014 apparently as a result of young becoming flighted and migration and swarming activity (Parsons et al. 2003). Activity was then greatly reduced after late September (Table 10, Figures 6a & 7a). The lack of increase in activity over the summer of 2013 (Table 10, Figure 7a) is likely a result of lost sensitivity of the microphones after rain events during the spring of that year. Winter activity from November through March was 2-3 orders of magnitude lower than activity during the active season and was relatively constant across the entire study period at 0.1 to 10 bat passes per night during most weeks when the detector was functioning (Table 10, Figures 6a & 7b).

Bat activity near the base of the wind turbine was basically limited to May through September, but single passes of an unidentified 30 kHz bat were recorded on 25 October 2013 and 17 November 2012 (Table 11, Figures 6b & 8). Bat activity near the base of the wind turbine was 2 orders of magnitude less than at the water treatment ponds during the active season and was essentially nonexistent between October and April (Tables 10 & 11, Figures 6-8).Patterns of bat activity observed at

the Landusky water treatment ponds and wind turbine site were generally consistent with other sites across the regional network of acoustic detectors that have been deployed between 2012 and 2015 (Figures 6-10). Across the network, bat activity begins to pick up by early to mid-April, rises steadily through June and then begins to decline again after peaks at some sites in late August through mid-September (Figures 9 & 10). Across the network, bat activity during the winter period is lowest between early December and late February and is 2 or 3 orders of magnitude less than what is recorded during the active season (Figures 9 & 10).

## Timing of Bat Activity

During the active season (April to October), bat activity at both the water treatment ponds and the wind turbine occurred throughout the night, but often exhibited a pulse of activity during the first two hours after sunset. Between June and September when nighttime temperatures are relatively warm, bat activity was bimodally pulsed with the second pulse occurring five to nine hours after sunset or two to five hours before sunrise (Figures 11a & 12). During the inactive season (November to April) there were no clear patterns in timing of activity at the water treatment ponds (Figure 11b).

## Temperature & Bat Activity

During the warmer months (June through September) at the water treatment ponds, minimum, maximum, and average nightly bat pass temperatures closely approximated minimum, maximum, and average nightly background temperatures indicating that bats were active during most temperatures that were available (Table 12, Figure 13a). A similar pattern was seen at the wind turbine site during the warmer months with average bat pass temperatures approximating average background temperatures (Table 13, Figure 13b). However, possibly resulting from the relatively low volume of bat passes at the turbine site, maximum bat pass temperatures were unexpectedly lower than maximum background temperatures and minimum bat pass temperatures were higher than minimum background temperatures (Table 13).

During cooler months (October through May) bat activity was too restricted at the wind turbine site to assess correlations with temperature. At the water treatment ponds, bats restricted their activity during cooler months to warmer time periods (Table 12, Figure 13a). Average and minimum nightly bat pass temperatures were up to 11°C and 22 °C warmer than nightly average and minimum background temperatures, respectively (Table 12). Nightly average bat pass temperatures usually did not go below 3 to 4 °C and the minimum nightly average for bat pass temperatures was 1.3 °C for 10 bat passes in January of 2013 (Table 12).

Across the entire study period, the percent of nighttime hours with various average background temperatures and average temperatures associated with bat passes for temperatures recorded at the Zortman weather station clearly show that bats are restricting their activity to higher temperatures (Figure 14). This same pattern holds across the entire detector network with more than 99 percent of bat activity restricted to temperatures above freezing and 97 percent of bat activity restricted to temperatures above 5 °C (Figure 15).

Monthly minimum bat pass temperatures confirmed for individual species was 22.4 °C for

Townsend's Big-eared Bat, ranged from 3.2 to 27.2 °C for Big Brown Bat, 13.8 to 23.9 °C for Spotted Bat, 9.4 to 24.6 °C for Eastern Red Bat, 7.4 to 23.9 °C for Hoary Bat, 4.9 to 25.1 °C for Silver-haired Bat, 10.8 to 24.7 °C for Western Small-footed Bat, 8.4 to 24.9 ° for Long-eared Myotis, 7 to 23.4 °C for Little Brown Myotis, and 5.5 to 21.4 °C for Long-legged Myotis (Tables 14 and 15). The minimum bat pass temperatures recorded for individual species were often higher than have been recorded on other detectors across the region network of detectors to-date (Table 16). This possibly indicates that roost sites for most species are somewhat distant from the detector locations and that bats may not be flying far from their roost sites during colder weather conditions in this relatively harsh landscape.

## Wind Speed & Bat Activity

Wind speeds at the ridgeline anemometer prior to installation of the turbine averaged 6.8 meters per second between November of 2005 and August of 2010; annual averages ranged between 6.3 and 7.3 meters per second (Table 17). Overall statistical correlations of wind speed data between the Zortman and Hays weather stations and the wind turbine nacelle from January 2013 through September 2014 were poor ($R^2 < 0.0009$). However, congruencies in wind speed patterns across these data sources were certainly evident during this time period (see examples in Figure 16). The poor overall statistical correlations are likely a result of variations resulting from movements of individual weather systems, daily warming and cooling patterns, and interactions with local topography. For example, wind direction data indicate that the winds at the Zortman and Hays weather stations are predominantly out of the west, but the Hays station also has a large proportion of readings coming from the east, possibly associated with regular down drafts from the Little Rockies (Figures 17a & 17b). Wind direction data from the anemometer on the ridgeline where the turbine would eventually be installed show that winds on the ridgeline often come out of either the north and northeast or south and southwest (Figure 17c). This does not correlate well with the directional data for the Zortman and Hays weather stations, but may be a result of local daily wind patterns in operation around Gold Bug Butte, Sugar Loaf Butte, Mission Peak, and Indian Peak.

Due to the lack of overall concordance between our four sources of wind information we felt that it would be best to show bat activity patterns in relation to wind speed data for the Zortman and Hays weather stations and the anemometer on the turbine nacelle (Figures 18-20). Bat activity patterns in relation to wind speed for these three sources indicate that bats are more active at wind speeds of 6 meters per second or less than would be expected if bat activity was randomly distributed across all wind speeds available to them. This pattern was most clear in association with wind data from the Zortman weather station where approximately 85% of bat passes at both the water treatment ponds and wind turbine detectors were associated with wind speeds of 2 meters per second or less and bat activity was much greater in the 0 and 1 meter per second wind speed classes than would be expected at random. Furthermore, only a tiny fraction of activity was associated with wind speeds of 5 meters per second or more (Figure 18). Patterns of bat activity in association with the wind data from the Hays weather station and the turbine nacelle more closely matched background wind patterns (Figures 19 & 20).

However, bat activity was typically greater than what would be expected if activity was randomly distributed across available wind speeds for wind speeds of 6 meters per second or less for both of these sites. There were also clearly unlikely associations in the Hays and wind turbine nacelle data with some bat activity associated with wind speeds of up to 15 meters per second and more than 10 percent of passes associated with wind speeds greater than 8 meters per second (Figures 19 & 20).

Across the entire detector network, bat activity was greater than expected at random for wind speeds less than 3 meters per second (Figure 21). Wind speeds less than 3 meters per second accounted for 73 percent of bat passes and wind speeds less than 6 meters per second accounted for 95 percent of bat passes (Figure 21). Given the relatively large distance between bat detectors and some weather stations, it seems likely that, if anything, bats probably restrict their flight to even lower wind speeds than the associations in Figure 21 indicate.

## Barometric Pressure & Activity

Most, 80 and 85 percent, of bat activity at the water treatment and wind turbine sites, respectively, was associated with little to no change (-1 to +1 millibars) in hourly barometric pressure and bat activity in these pressure change classes was much greater than would be expected if bat activity were randomly distributed across background pressure change classes that were recorded (Figure 22).

Across the detector network, bat activity was greater than expected during negative changes (-1 to -3 millibars) in hourly barometric pressure and was less than expected with neutral or positive changes (1 to 2 millibars) in hourly barometric pressure than if it were randomly distributed across background pressure change classes (Figure 23). However, 77 percent of bat activity across the entire detector network was associated with little to no change (-1 to +1 millibars) in hourly barometric pressure (Figure 23).

## Precipitation & Bat Activity

Nighttime precipitation events in the Little Rockies are rare with only 3 percent of nighttime hours associated with precipitation at the Zortman weather station (Figure 24). Furthermore, the Zortman weather station was approximately 5.4 and 5.9 kilometers from the turbine and water treatment pond bat detectors, respectively, precipitation was coded in hourly bins, and bats are capable of flight within minutes after the passage of storm fronts. Given these limitations and while the magnitude of the effect is small, bat activity at both the water treatment ponds and wind turbine site was greater during hours without precipitation than would be expected if bat activity was randomly distributed between hours with and without precipitation (Figure 24). This same small magnitude pattern of greater bat activity than expected at random during hours without precipitation was evident across the entire detector network (Figure 25).

## Moonlight & Bat Activity

In a very clear trend, bat activity, as measured by the percentage of hours with bat passes, at the water treatment ponds was progressively greater than would be expected at random during moon illumination levels below 0.6 and progressively lower than would be expected at random during moon illumination levels above 0.6 (Figure 26a). Bat activity levels were generally higher than expected at random at

lower moon illumination levels and lower than would be expected at random at higher moon illumination levels at the wind turbine site (Figure 26b). However, the trend was not progressive and was not as clear. While bat activity was greater than would be expected at random during moon illumination levels between 0.2 and 0.4, the percentage of hours with bat activity at moon illumination levels of 0.1 and 0.0 was actually less than would be expected if bat activity was randomly distributed across moon illumination classes. The most likely cause of the disparity in trends of bat activity relative to available hours of moon illumination at the wind turbine site is that the wind turbine site receives so little bat activity, only 937 bat passes over nearly two years of detector deployment, that a small amount of activity during particular moon illumination phases has a relatively large impact.

Across the regional network of bat detectors, the same general trends of progressively greater than expected percentages of hours of bat activity during available hours at moon illuminations less than 0.5 and progressively less than expected percentages of hours of bat activity during available hours at moon illuminations greater than 0.5 is evident (Figure 27). The importance of moon illumination to bat activity across the regional detector network is further demonstrated by the increase in the magnitude of increased bat activity relative to expected at illuminations less than 0.5 when the moon is below the horizon as compared to when it is above the horizon. Similarly, the decrease in the magnitude of the decreased bat activity relative to expected at illuminations greater than 0.5 when the moon is below the horizon as compared to when it is above the horizon, also strongly supports the consistent importance of moon illumination to overall bat activity across the regional detector network.

## SPECIES ACTIVITY PATTERNS

Identification of individual species activity patterns was hindered by relatively low and potentially inconsistent rates of auto-identification of call sequences to species at both the water treatment ponds and wind turbine detectors (Tables 3 & 4, Maxell 2015). Furthermore, bat activity at the wind turbine was so limited that any patterns of activity for individual species at that location might have resulted from relatively random transient events. Only Big Brown Bat, Hoary Bat, Silver-haired Bat, Western Small-footed Myotis, Long-eared Myotis, and Little Brown Myotis had relatively high rates of confirmation of monthly presence (Table 6) and enough calls auto-identified to examine trends. Call sequences of known species identity in the Montana Bat Call Library have also had relatively high accuracy rates (>50 percent correct auto-identification rates) for these species. However, activity patterns for these species from auto-identified call sequences should still be regarded as speculative due to a variety of issues that might cause auto-identifications to be inaccurate and/or inconsistent (Maxell 2015).

Of the six species for which there is at least some justification for showing potential patterns of documented activity from auto-identified call sequences, there were three consistent overall patterns evident across all six species in average nightly passes per week (Figures 28 through 33). First, activity levels at the water treatment ponds were one to two orders of magnitude higher at the water treatment ponds than at the wind turbine

(Figures 28a-33a versus Figures 28b-33b). Second, activity was reduced during the 2013 active season at both the wind turbine and water treatment ponds as compared to other active seasons detectors were in place. Third, with the exception of 2013, activity levels generally were low in April and May, rose in June, peaked in July, and then tapered off between late September and early November to no passes at the wind turbine and exceedingly low numbers of passes at the water treatment ponds throughout the winter months.

At the water treatment ponds, there were two groupings of activity levels across species. Big Brown Bat, Silver-haired Bat, Western Small-footed Myotis, and Little Brown Myotis, all species for which there is evidence of year-round activity across the regional detector network (Table 9), had peak average numbers of nightly passes per week of 55 to 90 (Figures 28, 30, 31, & 33). Hoary Bat and Long-eared Myotis, species for which there is no confirmation of activity between December and March across the regional detector network (Table 9), had peak average numbers of nightly passes per week of 12 to 16 (Figures 29 & 32). While Hoary Bat activity was relatively low compared to other species at the water treatment ponds, it had among the highest average number of nightly passes per week at the wind turbine during June and July (Figures 28-33). This is probably simply indicative of the fact that this species is more of an open air flier than other species. But, it is also indicative that the Landusky wind turbine probably poses a relatively higher risk to this species as compared to others, especially when considering the higher mortality rates documented at wind turbine facilities (Table 1).

## Availability of Data Summaries

The latest tabular and chart data summaries for bat activity patterns in association with time, weather, and other correlates for detectors across the regional network of ultrasonic acoustic monitoring stations are available by request from the Montana Natural Heritage Program through an Excel workbook. Pivot tables and charts in topical worksheets in this workbook can be filtered to produce the latest data summaries for one or more sites, time periods, and species.

As confirmations of individual species monthly presence and minimum temperatures of activity are made, this information is added to the animal point observation database at the Montana Natural Heritage Program and is available to agency biologists and resource managers for regional and project-level planning online in the context of a variety of map information through the MapViewer web application http://mtnhp.org/mapviewer/

# Management Recommendations

The above measures of overall bat activity near detectors, hand confirmed presence of individual species by month, and hand confirmed minimum temperatures associated with bat passes of individual species are all stable metrics upon which management recommendations can be made. However, patterns of activity of individual species resulting from automated analyses should be used with a great deal of caution due to low rates of species assignment and low or uncertain rates of accuracy of those assignments. Furthermore, while bat activity near the base of the turbine was minimal and generally limited to May through September, it should be noted that bat activity at the height of the turbine's nacelle was not monitored during this study and activity of high flying bats (e.g., Eastern Red Bat, Hoary Bat, and Silver-haired Bat, the three species that have suffered approximately 75% of the documented mortalities associated with wind turbines across North America (Kunz et al. 2007)) in the vicinity of the blades may not have been recorded. Thus, the following management recommendations avoid use of activity patterns of individual species as determined by automated analyses and instead rely on results of hand confirmed analyses, general patterns of bat activity that were recorded at the study site, and results of published studies of wind turbine impacts on bat species.

The following management recommendations for the Landusky wind turbine and habitats across the Landusky Mine site are based on information gathered during this study, compilations of literature on the impacts of wind turbines on bats (Table 1, Appendix A, see especially Schuster et al. 2015), new voluntary best management practices adopted by the American Wind Energy Association (AWEA 2015), and literature and documentation in Montana's animal point observation database on the roosting habits and habitats of Montana's bat species (Appendix 5 in Maxell 2015, MTNHP 2015).

Management recommendations include: (1) setting the turbine cut-in speed to $\geq$ 6.0 m/sec between April and October – especially important in July during peak bat activity when young are newly flighted, and August, September, and October when migratory species are passing through and local bats are swarming and breeding; (2) feathering the blades, or making them parallel to wind direction, when wind speeds are <6 m/sec so that they rotate at fewer than 1-3 revolutions per minute between April and October; (3) maintaining grassland habitats near the base of the detector to avoid attraction of bats to potential tree roost sites or insects; (4) avoiding creation of pond habitats on the ridge that the wind turbine is on and, when and where possible, eliminate pond habitats near the turbine (e.g., holding ponds near road due south of the detector) to avoid attraction of bats to drinking areas; (5) protecting potential natural roost sites away from the turbine by conserving large diameter trees (especially snags with loose bark), rock outcrops, and cliff crevices; (6) maintaining accessibility of underground mine entrances that bats may be using as summer or winter roosts; and (7) installing bat houses on warm south and west facing walls of mine buildings that are distant from the turbine to provide summer roosting habitat and avoid bat use of internal portions of mine buildings.

# Literature Cited


Agnarsson I, C.M. Zambrana-Torrelio, N.P. Flores-Saldana, and L.J. May-Collado. 2011. A time-calibrated species-level phylogeny of bats (Chiroptera, Mammalia). PLOS Currents Tree of Life. 2011 Feb 4. Edition 1. doi: 10.1371/currents.RRN1212.

Agranat, I. 2014. Detecting bats with ultrasonic microphones: understanding the effects of microphone variance and placement on detection rates. Unpublished white paper. Wildlife Acoustics, Maynard, MA. 14 p.

[AWEA] American Wind Energy Association. 2015. Wind energy industry announces new voluntary practices to reduce overall impacts on bats by 30 percent. American Wind Energy Association Press Release. September 3, 2015. Accessed at: http://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=7833

Arnett, E.B., W.K. Brown, W.P. Erickson, J.K. Fiedler, B.L. Hamilton, T.H. Henry, A. Jain, G.D. Johnson, J. Kerns, R.R. Koford, C.P. Nicholson, T.J. O'Connell, M.D. Piorkowski, and R.D. Tankersley, Jr. 2008. Patterns of bat fatalities at wind energy facilities in North America. Journal of Wildlife Management 72(1):61-78.

Arnett, E.B., M.M.P. Huso, M.R. Schirmacher, and J.P. Hayes. 2011. Altering turbine speed reduces bat mortality at wind-energy facilities. Frontiers in Ecology and the Environment 9(4):209-214.

Baerwald, E.F., J. Edworthy, M. Holder, and R.M.R. Barclay. 2009. A large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. Journal of Wildlife Management 73(7):1077-1081.

Barclay, R.M. and L.D. Harder. 2003. Life histories of bats: life in the slow lane. Pp. 209-256 In: T.H. Kunz and M.B. Fenton (eds.) Bat Ecology. Chicago: University of Chicago Press. 779 p.

Bernard, R.F., J.T. Foster, E.V. Willcox, K.L. Parise, and G.F. McCracken. 2015. Molecular detection of the causative agent of White-nose Syndrome on Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) and two species of migratory bats in the southeastern USA. Journal of Wildlife Diseases 51(2):519-522.

Blehert, D.S., A.C. Hicks, M. Behr, C.U. Meteyer, B.M. Berlowski-Zier, E.L. Buckles, J.T.H. Coleman, S.R. Darling, A. Gargas, R. Niver, J.C. Okoniewski, R.J. Rudd, and W.B. Stone. 2008. Bat white-nose syndrome: an emerging fungal pathogen? Science 323: 227. DOI: 10.1126/science.1163874

Blehert, D.S., J.M. Lorch, A.E. Ballmann, P.M. Cryan, and C.U. Meteyer. 2011. Bat white-nose syndrome in North America. Microbe Magazine 6:267-273.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 3 February 2012. Emergency assessment concludes that three bat species are endangered in Canada. http://www.cosewic.gc.ca/eng/sct7/Bat_Emergency_Assessment_Press_Release_e.cfm

Cryan, P.M. 2008. Mating behavior as a possible cause of bat fatalities at wind turbines. Journal of Wildlife Management 72(3): 845-849.

Frank, C.L., A. Michalski, A.A. McDonough, M. Rahimian, R.J. Rudd, and C. Herzog. 2014. The resistance of a North American bat species (*Eptesicus fuscus*) to White-Nose Syndrome (WNS). Plos One 9:e113958. DOI:10.1371/2Fjournal.pone.0113958.

Frick W.F., J.F. Pollock, A.C. Hicks, K.E. Langwig, D.S. Reynolds, G.G. Turner, C.M. Butchkoski, and T.H. Kunz. 2010. An emerging disease causes regional population collapse of a common North American bat species. Science 329:679–682. DOI:10.1126/science.1188594.

Hayes, M. 2013. Bats killed in large numbers at United States wind energy facilities. BioScience 63(12):975-979.

Heffernan, L. 2014. White-Nose Syndrome (WNS) occurrence by county/district. 3 September 2014. https://www.whitenosesyndrome.org/sites/default/files/resource/wns_map_09-03-14.jpg

Hendricks, P. 1998. Bat surveys of Azure Cave and the Little Rocky Mountains: 1997-1998. Montana Natural Heritage Program. Helena, MT. 21 pp.

Hendricks, P., D.L. Genter, and S. Martinez. 2000. Bats of Azure Cave and the Little Rocky Mountains, Montana. Canadian Field-Naturalist 114:89-97.

Johnson, G.D., M.K. Perlik, W.P. Erickson, and M.D. Strickland. 2004. Bat activity, composition, and collision mortality at large wind plant in Minnesota. Wildlife Society Bulletin 32(4):1278-1288.

Johnson J.S., D.M. Reeder DM, J.W. McMichael III, M.B. Meierhofer, D.W.F. Stern, S.S. Lumadue, L.E. Sigler, H.D. Winters, M.E. Vodzak, A. Kurta, J.A. Kath, and K.A. Field. 2014. Host, pathogen, and environmental characteristics predict white-nose syndrome mortality in captive little brown myotis (*Myotis lucifugus*). PLoS ONE 9(11): e112502. DOI:10.1371/journal.pone.0112502

Kunz, T.H., E.B. Arnett, W.P. Erickson, A.R. Hoar, G.D. Johnson, R.P. Larkin, M.D. Strickland, R.W. Thresher, and M.D. Tuttle. 2007. Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. Frontiers in Ecology and the Environment 5(6):315-324.

Kunz, T.H. and J.D. Reichard. 2010. Status review of the Little Brown Myotis (*Myotis lucifugus*) and determination that immediate listing under the Endangered Species Act is scientifically and legally warranted. 30 pp.

Langwig, K.E., W.F. Frick, J.T. Bried, A.C. Hicks, T.H. Kunz, and A.M. Kilpatrick. 2012. Ecology Letters 15:1050-1057. DOI: 10.1111/j.1461-0248.2012.01829.x

Langwig, K.E., W.F. Frick, R. Reynolds, K.L. Parise, K.P. Drees, J.R. Hoyt, T.L. Cheng, T.H. Kunz, J.T. Foster, and A.M. Kilpatrick. 2014. Host and pathogen ecology drive the seasonal dynamics of a fungal disease, white-nose syndrome. Proceedings Royal Society B 282: 20142335. DOI: 10.1098/rspb.2014.2335

Lausen, C.L. and R.M.R. Barclay. 2006. Winter bat activity in the Canadian prairies. Canadian Journal of Zoology 84:1079-1086.

Lorch J.M., C.U. Meteyer, M.J. Behr, J.G. Boyles, P.M. Cryan, A.C. Hicks, A.E. Ballmann, J.T.H. Coleman, D.N. Redell, D.M. Reeder, and D.S. Blehert. 2011. Experimental infection of bats with *Geomyces destructans* causes white-nose syndrome. Nature 480:376–378. DOI:10.1038/nature10590.

Maxell, B.A., J. Cummins, R. Donovan, and J.L. Chaffin. 2014. Azure Cave survey report for 18 March 2014. Montana Natural Heritage Program. Helena, MT. 28 p.

Maxell, B.A., E. Whittle, I. Chechet, and C. Whittle. 2015. Azure Cave survey report for 19 April 2015. Montana Natural Heritage Program. Helena, MT. 28 p.

Maxell, B.A. Coordinator. 2015. Montana Bat and White-Nose Syndrome Surveillance Plan

and Protocols 2012-2016. Montana Natural Heritage Program. Helena, MT. 185 p.

Minnis, A.M. and D.L. Lindner. 2013. Phylogenetic evaluation of *Geomyces* and allies reveals no close relatives of *Pseudogymnoascus destructans*, comb. nov., in hibernacula of eastern North America. Fungal Biology 117(9):638-649.

[MTNHP] Montana Natural Heritage Program. 2015. Animal point observation database. Montana Natural Heritage Program. Helena, MT. Accessed September 2015.

Parsons, K.N., G. Jones, and F. Greenaway. 2003. Swarming activity of temperate zone microchiropteran bats: effects of season, time of night and weather conditions. Journal of Zoology 261:257-264.

Parsons, S. and J.M. Szewczak. 2009. Detecting, recording, and analyzing the vocalizations of bats. Pp. 91-111 In: Kunz, T.H. and S. Parsons. Ecological and behavioral methods for the study of bats. 2nd edition. Johns Hopkins University Press. Baltimore, MD.

Poulton, V. and W. Erickson. 2010. Post-construction bat and bird fatality study Judith Gap Wind Farm Wheatland County, Montana. Final Report. Results from June-October 2009 study and comparison with 2006-2007 study. Western Ecosystems Technology, Inc. 2003 Central Avenue, Cheyenne, WY. 35 p.

Schuster, E., L. Bulling, and J. Koppel. 2015. Consolidating the state of knowledge: a synoptical review of wind energy's wildlife effects. Environmental Management 56:300-331.

Smallwood, K.S. 2013. Comparing bird and bat fatality-rate estimates among North American wind-energy projects. Wildlife Society Bulletin 37(1):19-33.

U.S. Fish and Wildlife Service. 2012. North American bat death toll exceeds 5.5 million from white-nose syndrome. News Release.

U.S. Fish and Wildlife Service. 2014. Bats affected by WNS. Accessed 22 December 2014. [https://www.whitenosesyndrome.org/about/bats-affected-wns](https://www.whitenosesyndrome.org/about/bats-affected-wns)

U.S. Fish and Wildlife Service. 2015. Endangered and threatened wildlife and plants; threatened species status for the Northern Long-eared Bat with 4(d) rule; final rule and interim rule. Federal Register 80(63):17974-18033.

Warnecke L., J.M. Turner, T.K. Bollinger, J.M. Lorch, V. Misra, P.M. Cryan, G. Wibbelt, D.S. Blehert, and C.K.R. Willis. 2012. Inoculation of bats with European *Geomyces destructans* supports the novel pathogen hypothesis for the origin of white-nose syndrome. Proceedings of the National Academy of Sciences 109:6999–7003. DOI:10.1073/pnas.1200374109

**Table 1.** Montana bat species, conservation status, and known or potential concerns from WNS and wind turbine facilities.

| Species | Conservation Status | Species known to be affected by White-Nose Syndrome / *P. destructans* | Species known to be subject to mortality at wind turbines* |
|---|---|---|---|
| Pallid Bat (*Antrozous pallidus*) = ANPA | G5 S3, MT SOC, BLM Sensitive, USFS Sensitive | No connection known at this time. | No mortalities documented in literature. |
| Townsend's Big-eared Bat (*Corynorhinus townsendii*) = COTO | G34 S3, MT SOC, BLM Sensitive, USFS Sensitive | Detected, but no diagnostic sign of WNS (USFWS 2014). Potential winter roost vector. | No mortalities documented in literature. |
| Big Brown Bat (*Eptesicus fuscus*) = EPFU | G5 S4 | Blehert et al. 2008, Langwig et al. 2012, 2014, Frank et al. 2014. | Johnson et al. 2004; Kunz et al. 2007; Arnett et al. 2008, 2011. |
| Spotted Bat (*Euderma maculatum*) = EUMA | G4 S3, MT SOC, BLM Sensitive, USFS Sensitive | No connection known at this time. | No mortalities documented in literature. |
| Silver-haired Bat (*Lasionycteris noctivagans*) = LANO | G5 S4, Potential MT SOC | Detected, but no diagnostic sign of WNS (Bernard et al. 2015, USFWS 2014). Potential regional migratory vector. | Johnson et al. 2004; Kunz et al. 2007; Arnett et al. 2008, 2011; Baerwald et al. 2009; Poulton and Erickson 2010. |
| Eastern Red Bat (*Lasiurus borealis*) = LABO | G5 SU, Potential MT PSOC | Detected, but no diagnostic sign of WNS (Bernard et al. 2015, USFWS 2014). Potential regional migratory vector. | Kunz et al. 2007; Arnett et al. 2008, 2011. |
| Hoary Bat (*Lasiurus cinereus*) = LACI | G5 S3, MT SOC | No connection known at this time. | Johnson et al. 2004; Kunz et al. 2007; Arnett et al. 2008, 2011; Baerwald et al. 2009; Poulton and Erickson 2010. |
| California Myotis (*Myotis californicus*) = MYCA | G5 S4 | Close relatedness to *M. leibii* indicates possible susceptibility (Agnarsson et al. 2011, Langwig et al. 2012) | No mortalities documented in literature. |
| Western Small-footed Myotis (*Myotis ciliolabrum*) = MYCI | G5 S4 | Relatively close relatedness to *M. lucifugus* indicates possible susceptibility (Frick et al. 2010, Agnarsson et al. 2011) | No mortalities documented in literature. |
| Long-eared Myotis (*Myotis evotis*) = MYEV | G5 S4 BLM Sensitive | Close relatedness to *M. sodalis* indicates possible susceptibility (Agnarsson et al. 2011, Langwig et al. 2012) | Kunz et al. 2007 |
| Little Brown Myotis (*Myotis lucifugus*) = MYLU | G3 S3, MT SOC | Blehert et al. 2008, Frick et al. 2010, Lorch et al. 2011, Warnecke et al. 2012, Johnson et al. 2014, Langwig et al. 2012, 2014. | Johnson et al. 2004; Kunz et al. 2007; Arnett et al. 2008, 2011. |
| Northern Myotis (*Myotis septentrionalis*) = MYSE | G1G3 SU, BLM Special Status, USFS Threatened, USFWS Listed Threatened | Blehert et al. 2008, Langwig et al. 2012, 2014, USFWS 2015. | Kunz et al. 2007; Arnett et al. 2008 |
| Fringed Myotis (*Myotis thysanodes*) = MYTH | G4 S3, MT SOC, BLM Sensitive | Relatively close relatedness to *M. lucifugus* indicates possible susceptibility (Frick et al. 2010, Agnarsson et al. 2011) | No mortalities documented in literature. |
| Long-legged Myotis (*Myotis volans*) = MYVO | G5 S4 BLM Sensitive | Close relatedness to *M. sodalis* indicates possible susceptibility (Agnarsson et al. 2011, Langwig et al. 2012) | No mortalities documented in literature. |
| Yuma Myotis (Myotis yumanensis) = MYYU | G5 S3S4, Potential MT SOC | Relatively close relatedness to *M. grisescens* indicates possible susceptibility (Agnarsson et al. 2011, USFWS 2014) | No mortalities documented in literature. |

*Unidentified Myotis species mortalities have also been reported at the Judith Gap Wind Farm (Poulton and Erickson 2010).

**Table 2.** Bat species present or potentially present in the Little Rocky Mountains prior to and during this study

| Species | Previous Documentation During Active Season [1] | Documented Periods of Activity During this Study | Documented or Potential Use of Hibernacula in Region [2] |
|---|---|---|---|
| Townsend's Big-eared Bat (*Corynorhinus townsendii*) [3] | 14 previous records | July 2014 | Azure Cave – 12 November 1998, 18 March 2014 |
| Big Brown Bat (*Eptesicus fuscus*) | 26 previous records | Year round | Azure Cave – 18 March 2014, 19 April 2015 |
| Spotted Bat (*Euderma maculatum*) | No previous records. | June through August | Migratory |
| Eastern Red Bat (*Lasiurus borealis*) | No previous records. | July through September | Migratory |
| Hoary Bat (*Lasiurus cinereus*) | 11 previous records | May through October | Migratory |
| Silver-haired Bat (*Lasionycteris noctivagans*) | 5 previous records | April through November | Believed until recently to be migratory, but acoustic evidence counters this |
| Western Small-footed Myotis (*Myotis ciliolabrum*) | 4 previous records | April through October | Azure Cave – 18 March 2014 |
| Long-eared Myotis (*Myotis evotis*) | 5 previous records | May through October | Potential |
| Little Brown Myotis (*Myotis lucifugus*) | 10 previous records | April through October | Azure Cave – 5 March 1993, 18 March 2014, 19 April 2015 |
| Fringed Myotis (*Myotis thysanodes*) | Captured on Missouri River ~60 km to the WSW in 2003 | Not documented | Probable migrant |
| Long-legged Myotis (*Myotis volans*) | 4 previous records | May to August | Azure Cave - 5 March 1993 |

[1] Records between April 1 and October 31 in the point observation database at the Montana Natural Heritage Program dating prior to the fall of 2011. Many of these are from Hendricks et al. 1998 and Hendricks et al. 1999.
[2] Records from Hendricks et al. 1998, Hendricks et al. 1999, Maxell et al. 2014, and Maxell et al. 2015.
[3] Species is very quiet acoustically, is often referred to as a "whispering" bat, and is often not detected at acoustic detectors with definitive call sequences.

**Table 3.** Deployment of detector/recorders and microphones at the Landusky Mine site

| Location | Device | Coordinates | Deployment Period | Comments |
|---|---|---|---|---|
| Water Treatment Ponds | Detector/Recorder | 47.90626<br>-108.62689 | 28 Sept 2011 through 29 Sept 2014 | Detector/recorder and microphones were checked and data were downloaded on 4 November 2011, 28 January 2012, 25 April 2012, 9 June 2012, 12 June 2012, 26 June 2012, 27 July 2012, 12 October 2012, 7 November 2012, 19 December 2012, 17 April 2013, 5 June 2013, 2 July 2013, 12 July 2013, 13 August 2013, 25 October 2013, 7 June 2014, and 29 September 2014. No data were gathered between 16 October and 3 November 2011, 11 January to 21 January 2013, due to insufficient battery charging from solar panel, between 28 April and 8 June in 2012 because a rodent severed the power cable, between 12 October and 7 November 2012 because an inappropriate trigger setting was inadvertently coded, between 8 and 19 December 2012 due to unknown causes, between 11 June 2013 and 13 August 2013 because microphones failed after being saturated with rain, between 15 September and 25 October 2013 for unknown reasons, 6 to 11, 19 to 24, and 26 December 2013, 1 to 15 and 23 to 24 January, 27 January to 13 February, 21 February to 4 March, and 22 to 25 March 2014 apparently as a result of cold weather conditions, and 5 August and 29 September 2014 for unknown reasons. Both left and right microphone sensitivity may have been compromised to some extent from March to September of 2013 due to precipitation events. The left microphone was also intentionally turned off between 28 July and 7 November 2012 to conserve memory and processing time. |
| | Right Microphone | 47.90596<br>-108.62657 | 28 Sept 2011 through 29 Sept 2014 | |
| | Left Microphone | 47.90615<br>-108.62738 | 4 Nov 2011 through 29 Sept 2014 | |
| Wind Turbine | Detector/Recorder and Microphone | 47.90804<br>-108.62003 | 12 Oct 2012 through 29 Sept 2014 | Detector/recorder and microphone were checked and data were downloaded on 7 November 2012, 19 December 2012, and 17 April 2013, 5 June 2013, 2 July 2013, 12 July 2013, 13 August 2013, 25 October 2013, 7 June 2014, and 29 September 2014. Microphone had greatly reduced sensitivity between April and 7 June 2014 because it was saturated with rain. |

**Table 4.** Detector status as measured by percent of calls auto-identified to species at water treatment ponds

| Year | Month | Total No. of Calls | No. Calls Classified to Species | % Auto-identified to Species |
|---|---|---|---|---|
| 2011 | September | 192 | 52 | 27.1% |
| 2011 | October | 641 | 165 | 25.7% |
| 2011 | November | 256 | 81 | 31.6% |
| 2011 | December | 39 | 11 | 28.2% |
| 2012 | January | 10 | 5 | 50.0% |
| 2012 | February | 23 | 8 | 34.8% |
| 2012 | March | 110 | 20 | 18.2% |
| 2012 | April | 194 | 43 | 22.2% |
| 2012 | May[1] | 0 | - | - |
| 2012 | June | 6936 | 632 | 9.1% |
| 2012 | July | 15694 | 2091 | 13.3% |
| 2012 | August | 22174 | 3894 | 17.6% |
| 2012 | September | 24666 | 2699 | 10.9% |
| 2012 | October[1] | 55 | 6 | 10.9% |
| 2012 | November | 100 | 21 | 21.0% |
| 2012 | December | 15 | 2 | 13.3% |
| 2013 | January | 32 | 6 | 18.8% |
| 2013 | February | 2 | 0 | 0.0% |
| 2013 | March | 28 | 5 | 17.9% |
| 2013 | April | 886 | 147 | 16.6% |
| 2013 | May | 5202 | 499 | 9.6% |
| 2013 | June[1] | 1396 | 28 | 2.0% |
| 2013 | July[1] | 0 | - | - |
| 2013 | August | 1834 | 235 | 12.8% |
| 2013 | September | 1550 | 191 | 12.3% |
| 2013 | October | 11 | 0 | 0.0% |
| 2013 | November | 13 | 2 | 15.4% |
| 2013 | December | 8 | 0 | 0.0% |
| 2014 | January | 0 | - | - |
| 2014 | February | 0 | - | - |
| 2014 | March | 2 | 0 | 0.0% |
| 2014 | April | 334 | 8 | 2.4% |
| 2014 | May | 1261 | 58 | 4.6% |
| 2014 | June | 3546 | 315 | 8.9% |
| 2014 | July | 19616 | 2725 | 13.9% |
| 2014 | August | 4527 | 373 | 8.2% |
| | | ∑ = 111353 | ∑ = 14322 | X = 12.9% |

[1] Detector/recorder/microphone/power/charging malfunction. See comments in table 3.

**Table 5.** Detector status as measured by percent of calls auto-identified to species at wind turbine

| Year | Month | Total No. of Calls | No. Calls Classified to Species | % Auto-identified to Species |
|---|---|---|---|---|
| 2012 | November | 1 | 1 | 100.0% |
| 2012 | December | 0 | - | - |
| 2013 | January | 0 | - | - |
| 2013 | February | 0 | - | - |
| 2013 | March | 0 | - | - |
| 2013 | April | 0 | - | - |
| 2013 | May | 6 | 0 | 0.0% |
| 2013 | June | 16 | 1 | 6.3% |
| 2013 | July | 33 | 0 | 0.0% |
| 2013 | August | 80 | 0 | 0.0% |
| 2013 | September | 17 | 0 | 0.0% |
| 2013 | October | 1 | 0 | 0.0% |
| 2013 | November | 0 | - | - |
| 2013 | December | 0 | - | - |
| 2014 | January | 0 | - | - |
| 2014 | February | 0 | - | - |
| 2014 | March | 0 | - | - |
| 2014 | April[1] | 0 | - | - |
| 2014 | May[1] | 3 | 0 | 0.0% |
| 2014 | June | 69 | 20 | 29.0% |
| 2014 | July | 275 | 72 | 26.2% |
| 2014 | August | 268 | 67 | 25.0% |
| 2014 | September | 168 | 50 | 29.8% |
| | | ∑ = 937 | ∑ = 211 | X = 22.5% |

[1] Detector/recorder/microphone/power/charging malfunction. See comments in table 3.

**Table 6.** Monthly rates of hand confirmation from automated analysis results, including automated identifications for the water treatment ponds and wind turbine detectors

| Species | No. months with automated identification of species | No. months with hand confirmed identification of species | % of months automated identification was hand confirmed |
|---|---|---|---|
| Pallid Bat (*Antrozous pallidus*) [1] | 12 | 0 | 0.0% |
| Townsend's Big-eared Bat (*Corynorhinus townsendii*) [2] | 18 | 1 | 5.6% |
| Big Brown Bat (*Eptesicus fuscus*) | 32 | 28 | 87.5% |
| Spotted Bat (*Euderma maculatum*) [3] | 1 | 1 | 100% |
| Eastern Red Bat (*Lasiurus borealis*) [4] | 26 | 4 | 15.4% |
| Hoary Bat (*Lasiurus cinereus*) | 20 | 13 | 65.0% |
| Silver-haired Bat (*Lasionycterus noctivagans*) | 27 | 19 | 70.4% |
| Western Small-footed Myotis (*Myotis ciliolabrum*) | 23 | 15 | 65.2% |
| Long-eared Myotis (*Myotis evotis*) | 14 | 14 | 100.0% |
| Little Brown Myotis (*Myotis lucifugus*) | 22 | 20 | 90.9% |
| Northern Myotis (*Myotis septentrionalis*) [5] | 3 | 0 | 0.0% |
| Fringed Myotis (*Myotis thysanodes*) [6] | 5 | 0 | 0.0% |
| Long-legged Myotis (*Myotis volans*) [7] | 11 | 1 | 9.1% |

[1] Some Pallid Bat calls overlap with some Big Brown Bat calls and these Big Brown Bat calls are often mistakenly identified by Sonobat 3.0 as Pallid Bat calls. Landusky is north of the known range of Pallid Bat (Maxell 2015).

[2] Species is relatively quiet and often does not create fully definitive echolocation call recordings on bat detectors.

[3] Additional Spotted Bat calls were identified through a different analysis process for this species (Maxell 2015).

[4] Some Eastern Red Bat calls overlap with some Little Brown Myotis calls and these Little Brown Myotis calls are often mistakenly identified by Sonobat 3.0 as Eastern Red Bat calls (Maxell 2015).

[5] Northern Myotis calls can overlap with some Long-eared Myotis, Little Brown Myotis, Fringed Myotis, and Long-legged Myotis calls and Sonobat 3.0 can mistakenly identify these calls as Northern Myotis. There is only a single record of Northern Myotis in Montana from near Culbertson in January of 1978 (Maxell 2015).

[6] Some Fringed Myotis echolocation calls can overlap with some Long-eared Myotis, Little Brown Myotis, and Long-legged Myotis calls. The closest record for this species to the study site is on the Missouri River approximately 60 km to the west-southwest in 2003 (Maxell 2015).

[7] Long-legged Myotis calls can overlap with Long-eared Myotis, Little Brown Myotis, and Fringed Myotis calls and rarely have call characteristics recorded that allow them to be definitively identified as Long-legged Myotis (Maxell 2015).

**Table 7.** Species definitively detected by month each year of the study at water treatment ponds[1, 2]

| Species | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Townsend's Big-eared Bat (*Corynorhinus townsendii*)[3] | | | | | | | 2014 | | | | | |
| Big Brown Bat (*Eptesicus fuscus*) | 2013 | 2012 | 2012 | 2013<br>2014 | 2013<br>2014 | 2012<br>2013<br>2014 | 2012<br>2014 | 2012<br>2013<br>2014 | 2011<br>2012<br>2013 | 2011<br>2012 | 2011<br>2012 | 2011<br>2012 |
| Spotted Bat (*Euderma maculatum*) | | | | | | 2012 | 2012<br>2014 | 2014 | | | | |
| Eastern Red Bat (*Lasiurus borealis*) | | | | | | | 2012 | 2012<br>2014 | | | | |
| Hoary Bat (*Lasiurus cinereus*) | | | | | 2013 | 2012<br>2014 | 2012<br>2014 | 2012<br>2013<br>2014 | 2012 | 2012 | | |
| Silver-haired Bat (*Lasionycteris noctivagans*) | | | | 2012<br>2013 | 2013 | 2012<br>2013<br>2014 | 2012<br>2014 | 2012<br>2013<br>2014 | 2012<br>2013 | 2011<br>2012 | 2011 | |
| Western Small-footed Myotis (*Myotis ciliolabrum*) | | | | 2012<br>2013 | 2013 | 2012<br>2014 | 2012<br>2014 | 2012<br>2013<br>2014 | 2011<br>2012 | 2011 | | |
| Long-eared Myotis (*Myotis evotis*) | | | | | 2013<br>2014 | 2012<br>2013<br>2014 | 2012<br>2014 | 2012<br>2013<br>2014 | 2011<br>2012<br>2013 | 2011 | | |
| Little Brown Myotis (*Myotis lucifugus*) | | | | 2012<br>2013 | 2013<br>2014 | 2012<br>2013<br>2014 | 2012<br>2014 | 2012<br>2013<br>2014 | 2011<br>2012<br>2013 | 2011 | | |
| Long-legged Myotis (*Myotis volans*) | | | | | | | | 2012 | | | | |

[1] Blue cells of table indicate documentation of the species in the region during this month prior to this study
[2] See comments in Table 3 on periods of time when there were detector/recorder, microphone, or power system malfunctions.
[3] Species is relatively quiet and often does not create fully definitive echolocation call recordings on bat detectors.

**Table 8.** Species definitively detected by month each year of the study at wind turbine [1]

| Species | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Brown Bat (*Eptesicus fuscus*) | | | | | | | 2013 2014 | 2013 2014 | 2014 | | | |
| Eastern Red Bat (*Lasiurus borealis*) | | | | | | | | | 2014 | | | |
| Hoary Bat (*Lasiurus cinereus*) | | | | | | 2014 | 2014 | 2014 | 2014 | | | |
| Silver-haired Bat (*Lasionycteris noctivagans*) | | | | | | 2014 | 2014 | 2014 | 2014 | | | |
| Western Small-footed Myotis (*Myotis ciliolabrum*) | | | | | | | 2014 | 2014 | | | | |
| Long-eared Myotis (*Myotis evotis*) | | | | | | | 2014 | 2013 2014 | 2014 | | | |
| Little Brown Myotis (*Myotis lucifugus*) | | | | | | 2014 | 2013 2014 | 2013 2014 | 2013 2014 | | | |
| Long-legged Myotis (*Myotis volans*) | | | | | 2014 | | | | | | | |

[1] Blue cells of table indicate documentation of the species in the region during this month prior to this study

**Table 9.** Species definitively detected by month across the acoustic detector network (blue cells) and at Landusky detectors (X)

| Species | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Townsend's Big-eared Bat [1] (*Corynorhinus townsendii*) | | | | | | | X | | | | | |
| Big Brown Bat (*Eptesicus fuscus*) | X | X | X | X | X | X | X | X | X | X | X | X |
| Spotted Bat (*Euderma maculatum*) | | | | | | X | X | X | | | | |
| Eastern Red Bat (*Lasiurus borealis*) | | | | | | | X | X | X | | | |
| Hoary Bat (*Lasiurus cinereus*) | | | | | X | X | X | X | X | X | | |
| Silver-haired Bat (*Lasionycteris noctivagans*) | | | | X | X | X | X | X | X | X | X | |
| Western Small-footed Myotis (*Myotis ciliolabrum*) | | | | X | X | X | X | X | X | X | | |
| Long-eared Myotis (*Myotis evotis*) | | | | | X | X | X | X | X | X | | |
| Little Brown Myotis (*Myotis lucifugus*) | | | | X | X | X | X | X | X | X | | |
| Long-legged Myotis (*Myotis volans*) | | | | | X | | | X | | | | |

[1] Species is relatively quiet and often does not create fully definitive echolocation call recordings on bat detectors.

**Table 10.** Bat passes summarized by month across all species at water treatment ponds

| Year | Month | Total no. bat passes | No. sample nights[1] | Avg no. of nightly passes | StDev of nightly passes | Min count of nightly bat passes | Max count of nightly bat passes |
|---|---|---|---|---|---|---|---|
| 2011 | 9 | 271 | 3 | 90.3 | 141.7 | 8 | 254 |
| 2011 | 10 | 562 | 15 | 37.5 | 80.2 | 0 | 281 |
| 2011 | 11 | 256 | 27 | 9.5 | 31.4 | 0 | 163 |
| 2011 | 12 | 39 | 22 | 1.8 | 3.9 | 0 | 14 |
| 2012 | 1 | 10 | 16 | 0.6 | 2.2 | 0 | 9 |
| 2012 | 2 | 23 | 29 | 0.8 | 2.5 | 0 | 11 |
| 2012 | 3 | 110 | 31 | 3.5 | 6.2 | 0 | 28 |
| 2012 | 4 | 194 | 27 | 7.2 | 8.8 | 0 | 31 |
| 2012 | 5 | 0 | 0 | - | - | - | - |
| 2012 | 6 | 7072 | 22 | 321.5 | 323.2 | 0 | 1159 |
| 2012 | 7 | 15558 | 27 | 576.2 | 247.8 | 242 | 1177 |
| 2012 | 8 | 22869 | 31 | 737.7 | 333 | 90 | 1156 |
| 2012 | 9 | 23989 | 30 | 799.6 | 662.9 | 53 | 2383 |
| 2012 | 10 | 37 | 18 | 2.1 | 6.1 | 0 | 26 |
| 2012 | 11 | 102 | 23 | 4.4 | 8.6 | 0 | 37 |
| 2012 | 12 | 13 | 20 | 0.6 | 1.4 | 0 | 4 |
| 2013 | 1 | 32 | 31 | 1 | 2.2 | 0 | 7 |
| 2013 | 2 | 2 | 28 | 0.1 | 0.4 | 0 | 2 |
| 2013 | 3 | 28 | 31 | 0.9 | 2.7 | 0 | 13 |
| 2013 | 4 | 886 | 30 | 29.5 | 79 | 0 | 288 |
| 2013 | 5 | 5202 | 31 | 167.8 | 176.8 | 0 | 548 |
| 2013 | 6 | 1396 | 30 | 46.5 | 100.1 | 0 | 371 |
| 2013 | 7 | 0 | 31 | 0 | 0 | 0 | 0 |
| 2013 | 8 | 1858 | 31 | 59.9 | 80.5 | 0 | 298 |
| 2013 | 9 | 1526 | 13 | 117.4 | 177 | 0 | 608 |
| 2013 | 10 | 11 | 7 | 1.6 | 2.7 | 0 | 6 |
| 2013 | 11 | 13 | 30 | 0.4 | 1.1 | 0 | 5 |
| 2013 | 12 | 8 | 15 | 0.5 | 1.4 | 0 | 4 |
| 2014 | 1 | 0 | 9 | 0 | 0 | 0 | 0 |
| 2014 | 2 | 0 | 8 | 0 | 0 | 0 | 0 |
| 2014 | 3 | 2 | 22 | 0.1 | 0.4 | 0 | 2 |
| 2014 | 4 | 364 | 30 | 12.1 | 24.8 | 0 | 84 |
| 2014 | 5 | 1231 | 31 | 39.7 | 53.4 | 0 | 267 |
| 2014 | 6 | 3562 | 30 | 118.7 | 104.5 | 2 | 349 |
| 2014 | 7 | 20571 | 31 | 663.6 | 337.9 | 34 | 1485 |
| 2014 | 8 | 3556 | 4 | 889 | 330.1 | 512 | 1297 |

[1] Number of nights the detector/recorder was powered and logging temperatures.See Table 3 for periods of time when microphones may not have been properly functioning.

**Table 11.** Bat passes summarized by month across all species at wind turbine

| Year | Month | Total no. bat passes | No. sample nights[1] | Avg no. of nightly passes | St Dev of nightly passes | Min count of nightly bat passes | Max count of nightly bat passes |
|---|---|---|---|---|---|---|---|
| 2012 | 10 | 0 | 20 | 0 | 0 | 0 | 0 |
| 2012 | 11 | 1 | 30 | 0 | 0.2 | 0 | 1 |
| 2012 | 12 | 0 | 31 | 0 | 0 | 0 | 0 |
| 2013 | 1 | 0 | 31 | 0 | 0 | 0 | 0 |
| 2013 | 2 | 0 | 28 | 0 | 0 | 0 | 0 |
| 2013 | 3 | 0 | 31 | 0 | 0 | 0 | 0 |
| 2013 | 4 | 0 | 30 | 0 | 0 | 0 | 0 |
| 2013 | 5 | 6 | 31 | 0.2 | 0.5 | 0 | 2 |
| 2013 | 6 | 16 | 30 | 0.5 | 0.8 | 0 | 3 |
| 2013 | 7 | 36 | 31 | 1.2 | 1.3 | 0 | 5 |
| 2013 | 8 | 77 | 31 | 2.5 | 2.1 | 0 | 9 |
| 2013 | 9 | 17 | 30 | 0.6 | 1 | 0 | 3 |
| 2013 | 10 | 1 | 31 | 0 | 0.2 | 0 | 1 |
| 2013 | 11 | 0 | 30 | 0 | 0 | 0 | 0 |
| 2013 | 12 | 0 | 31 | 0 | 0 | 0 | 0 |
| 2014 | 1 | 0 | 31 | 0 | 0 | 0 | 0 |
| 2014 | 2 | 0 | 28 | 0 | 0 | 0 | 0 |
| 2014 | 3 | 0 | 31 | 0 | 0 | 0 | 0 |
| 2014 | 4 | 0 | 30 | 0 | 0 | 0 | 0 |
| 2014 | 5 | 3 | 31 | 0.1 | 0.3 | 0 | 1 |
| 2014 | 6 | 70 | 30 | 2.3 | 2.9 | 0 | 10 |
| 2014 | 7 | 292 | 31 | 9.4 | 7.1 | 0 | 30 |
| 2014 | 8 | 262 | 31 | 8.5 | 6.1 | 0 | 25 |
| 2014 | 9 | 156 | 29 | 5.4 | 5.8 | 0 | 22 |

[1] Number of nights during month when the detector/recorder was functioning properly.

**Table 12.** Nightly background and bat pass temperatures summarized by month at treatment ponds

| Year | Month | Background Temp C Avg (SD) N | Bat Pass Temp C Avg (SD) N | Background Min Temp C | Bat Pass Min Temp_C | Background Max Temp C | Bat Pass Max Temp C |
|---|---|---|---|---|---|---|---|
| 2011 | 9 | 18.2 (4.5) 248 | 23.6 (3.9) 271 | 10.5 | 11.3 | 28.7 | 27.7 |
| 2011 | 10 | 13.6 (6.3) 2487 | 22.3 (3.2) 562 | 1.9 | 9.5 | 29 | 27.9 |
| 2011 | 11 | 3.2 (5.9) 4738 | 9.5 (2.3) 256 | -15.8 | 4.4 | 25.4 | 14.1 |
| 2011 | 12 | 4.1 (3.6) 2306 | 6.8 (2.4) 39 | -7.1 | 3.6 | 11.2 | 10.3 |
| 2012 | 1 | 5.7 (3.6) 1424 | 8 (0.6) 10 | -6.3 | 7.5 | 13.5 | 9.2 |
| 2012 | 2 | -0.2 (4.2) 4794 | 5.2 (0.5) 23 | -12.2 | 4.4 | 11.5 | 6.7 |
| 2012 | 3 | 6.7 (5.1) 4493 | 10.6 (3.1) 110 | -7.6 | 3.7 | 17.4 | 17.3 |
| 2012 | 4 | 9.7 (5.5) 3387 | 15.2 (5.6) 194 | -4.1 | 4.2 | 32.2 | 22.6 |
| 2012 | 5 | [1] | [1] | [1] | [1] | [1] | [1] |
| 2012 | 6 | 17.1 (4.2) 2032 | 19.1 (3.3) 7072 | 6.7 | 10.3 | 27.5 | 27.5 |
| 2012 | 7 | 23.2 (3.4) 2671 | 23 (3.4) 15558 | 14.3 | 15.3 | 30.3 | 30.3 |
| 2012 | 8 | 19.4 (4.8) 3560 | 20.9 (3.8) 22869 | 6.7 | 6.9 | 30.2 | 30.2 |
| 2012 | 9 | 15.4 (3.6) 4101 | 16.8 (3) 23989 | 7.2 | 8 | 26 | 26 |
| 2012 | 10 | 6.7 (5.1) 2903 | 17 (3.3) 37 | -2.1 | 5.5 | 20.1 | 19.3 |
| 2012 | 11 | 3.7 (5.7) 4019 | 8.5 (2.8) 102 | -14.7 | 3.6 | 13.8 | 13 |
| 2012 | 12 | -0.6 (6.6) 3649 | 5.5 (2.2) 13 | -17.8 | 3.6 | 12.3 | 9.2 |
| 2013 | 1 | -0.1 (6.4) 5610 | 4.6 (2.6) 32 | -17.8 | 1.3 | 10.7 | 10 |
| 2013 | 2 | 1.2 (3.7) 4623 | 8.2 (0) 2 | -10.7 | 8.2 | 10 | 8.2 |
| 2013 | 3 | 1.8 (6) 4482 | 9.7 (1) 28 | -13.5 | 8.7 | 12.5 | 11.5 |
| 2013 | 4 | 4.4 (5.9) 3717 | 13.9 (2.3) 886 | -7.7 | 4.7 | 17.9 | 17.6 |
| 2013 | 5 | 13 (3.9) 3288 | 15.4 (2.8) 5202 | -3.1 | 3.1 | 24.2 | 23.9 |
| 2013 | 6 | 16.1 (3.8) 2908 | 16.6 (1.5) 1396 | 2.2 | 9.5 | 24.4 | 21.4 |
| 2013 | 7 | [1] | [1] | [1] | [1] | [1] | [1] |
| 2013 | 8 | 22 (3.4) 3652 | 22.6 (2.3) 1858 | 12.3 | 14.5 | 29.5 | 29.5 |
| 2013 | 9 | 21.7 (3.6) 1788 | 23.3 (2.1) 1526 | 12.3 | 14.5 | 30.7 | 30.7 |
| 2013 | 10 | 4.8 (5.3) 1097 | 12.5 (2) 11 | -7.1 | 9.5 | 18.4 | 15.6 |
| 2013 | 11 | 3.3 (5.4) 5324 | 11.8 (3.8) 13 | -17.7 | 4.9 | 16.1 | 16 |
| 2013 | 12 | -0.9 (10.2) 2139 | 8.7 (3.4) 8 | -20.5 | 5.5 | 12.8 | 12 |
| 2014 | 1 | [1] | [1] | [1] | [1] | [1] | [1] |
| 2014 | 2 | [1] | [1] | [1] | [1] | [1] | [1] |
| 2014 | 3 | 4.5 (4.4) 2879 | 7 (0) 2 | -12.9 | 7 | 12.7 | 7 |
| 2014 | 4 | 7.2 (4.6) 3689 | 12.4 (2.8) 364 | -6.1 | 4.9 | 20.6 | 16.5 |
| 2014 | 5 | 11.9 (5.4) 3294 | 15.7 (4.3) 1231 | -0.5 | 3.1 | 24.2 | 24.2 |
| 2014 | 6 | 14.4 (2.9) 2931 | 16.2 (2.6) 3562 | 4.9 | 7.9 | 21.7 | 21.7 |
| 2014 | 7 | 21.3 (3.4) 3154 | 21.8 (3.3) 20571 | 13.8 | 14.5 | 29.5 | 29.5 |
| 2014 | 8 | 23.3 (1.5) 498 | 22.5 (1.4) 3556 | 17.8 | 20.4 | 26.9 | 26.9 |
| 2014 | 9 | [1] | [1] | [1] | [1] | [1] | [1] |

[1] Detector/recorder/microphone/power/charging malfunction. See comments in Table 3.

**Table 13.** Nightly background and bat pass temperatures summarized by month at wind turbine[1]

| Year | Month | Background Temp C Avg (SD) N | Bat Pass Temp C Avg (SD) N | Background Min Temp C | Bat Pass Min Temp C | Background Max Temp C | Bat Pass Max Temp C |
|---|---|---|---|---|---|---|---|
| 2012 | 10 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2012 | 11 | -4 (6.6) 27103 | 5.2 ([3]) 1 | -15.5 | 5.2 | 14 | 5.2 |
| 2012 | 12 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2013 | 1 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2013 | 2 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2013 | 3 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2013 | 4 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2013 | 5 | 11.2 (4) 3319 | 16 (4.7) 6 | -4.8 | 11.2 | 22.4 | 21.7 |
| 2013 | 6 | 14 (3.7) 2921 | 16.3 (2.1) 16 | 3.2 | 11.2 | 22.2 | 19.6 |
| 2013 | 7 | 18.1 (3.1) 3173 | 18 (1.9) 36 | 10.7 | 13.6 | 25.4 | 21.6 |
| 2013 | 8 | 19.6 (3.5) 3664 | 18.6 (4) 77 | 12 | 12.2 | 26.5 | 26.4 |
| 2013 | 9 | 15.1 (5.7) 4156 | 20.6 (2.5) 17 | 2.6 | 16.6 | 29 | 24.1 |
| 2013 | 10 | 6.1 (4.5) 4945 | 9 ([3]) 1 | -6.7 | 9 | 17.4 | 9 |
| 2013 | 11 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2013 | 12 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2014 | 1 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2014 | 2 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2014 | 3 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2014 | 4 | [2] | [2] | [2] | [2] | [2] | [2] |
| 2014 | 5 | 10.2 (5.3) 3316 | 9.3 (3.3) 3 | -0.5 | 5.5 | 22.2 | 11.2 |
| 2014 | 6 | 12.4 (2.9) 2915 | 14.6 (2.3) 70 | 4.9 | 8 | 19.6 | 18.9 |
| 2014 | 7 | 19 (3.3) 3154 | 19.8 (3.3) 292 | 11.7 | 12 | 26.9 | 26.7 |
| 2014 | 8 | 18.1 (4.4) 3649 | 19 (3.8) 262 | 5.9 | 8.9 | 26.2 | 26 |
| 2014 | 9 | 13.4 (6) 3920 | 15.2 (3.8) 156 | -0.1 | 1.9 | 25.7 | 21.4 |

[1] Temperatures should only be regarded as being indicative of the general temperature at the time of detection. Temperatures were recorded at the detector approximately 1 meter above ground level while microphones were mounted at approximately 3 meters above ground level and bats were in flight at an unknown altitude, but probably typically within 30 meters of ground level. Temperatures of the bat's roost environment at the time flights were initiated are also obviously unknown.

[2] No calls recorded.

[3] Cannot calculate standard deviation with a single value.

**Table 14.** Monthly minimum bat pass temperatures (°C) recorded for individual species hand confirmed as definitively present at water treatment ponds [1]

| Species[2] | Year | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COTO | 2014 | | | | | | | 22.4 | | | | | |
| EPFU | 2011 | | | | | | | | | 27.2 | 20.4 | 9.4 | 7 |
| EPFU | 2012 | | 4.7 | 3.7 | 18.9 | | 16.8 | 23.6 | 20.1 | 17.3 | 11.7 | 3.6 | 3.6 |
| EPFU | 2013 | 3.2 | | | 5.7 | 15.6 | 16.3 | | 25.7 | 25.2 | | | |
| EPFU | 2014 | | | | 12 | 16.6 | 15.5 | 18.6 | 23.6 | | | | |
| EUMA | 2012 | | | | | | 13.8 | 23.9 | | | | | |
| EUMA | 2014 | | | | | | | 20.3 | 23.2 | | | | |
| LABO | 2012 | | | | | | | 20.3 | 21.2 | | | | |
| LABO | 2014 | | | | | | | | 24.6 | | | | |
| LACI | 2012 | | | | | | 12.7 | 23.7 | 8.7 | 19.1 | 14.3 | | |
| LACI | 2013 | | | | | 17.8 | | | 19.6 | | | | |
| LACI | 2014 | | | | | | 16 | 19.8 | 23.9 | | | | |
| LANO | 2011 | | | | | | | | | | 12.3 | 4.9 | |
| LANO | 2012 | | | | 19.3 | | 20.3 | 24.6 | 25.1 | 16.3 | 19.3 | | |
| LANO | 2013 | | | | 14.3 | 10.7 | 16.6 | | 23.9 | 15.5 | | | |
| LANO | 2014 | | | | | | 12 | 17 | 23.6 | | | | |
| MYCI | 2011 | | | | | | | | | 23.7 | 24.4 | | |
| MYCI | 2012 | | | | 10.8 | | 20.3 | 21.1 | 19.8 | 21.7 | | | |
| MYCI | 2013 | | | | 15.6 | 14 | | | 19.3 | | | | |
| MYCI | 2014 | | | | | | 16 | 24.7 | 22.1 | | | | |
| MYEV | 2011 | | | | | | | | | 11.7 | 24.9 | | |
| MYEV | 2012 | | | | | | 17.3 | 18.8 | 17.1 | 8.4 | | | |
| MYEV | 2013 | | | | | 11.7 | 15 | | 23.7 | 23.4 | | | |
| MYEV | 2014 | | | | | 17.6 | 14 | 17.4 | 23.6 | | | | |
| MYLU | 2011 | | | | | | | | | 23.4 | 22.1 | | |
| MYLU | 2012 | | | | 20.8 | | 13.2 | 17.8 | 7 | 11 | | | |
| MYLU | 2013 | | | | 9.2 | 9.8 | 16.1 | | 20.9 | 15.5 | | | |
| MYLU | 2014 | | | | | 19.4 | 10.5 | 15.8 | 21.1 | | | | |
| MYVO | 2012 | | | | | | | | 21.4 | | | | |

[1] Temperatures should only be regarded as being indicative of the general temperature at the time of detection. Temperatures were recorded at the detector approximately 1 meter above ground level while microphones were mounted at approximately 3 meters above ground level and bats were in flight at an unknown altitude, but probably typically within 30 meters of ground level. Temperatures of the bat's roost environment at the time flights were initiated are also obviously unknown.

[2] Species codes are the first two letters of the genus and species names.

**Table 15.** Monthly minimum bat pass temperatures (°C) recorded for individual species at wind turbine[1]

| Species[2] | Year | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPFU | 2013 | | | | | | | 15.6 | 15.5 | | | | |
| EPFU | 2014 | | | | | | | 20.1 | 21.4 | 21.4 | | | |
| LABO | 2014 | | | | | | | | | 9.4 | | | |
| LACI | 2014 | | | | | | 12 | 19.9 | 14 | 7.4 | | | |
| LANO | 2014 | | | | | | 14.5 | 19.1 | 22.1 | 17.8 | | | |
| MYCI | 2014 | | | | | | | 24.7 | 23.2 | | | | |
| MYEV | 2013 | | | | | | | | 21.9 | | | | |
| MYEV | 2014 | | | | | | | 18.3 | 20.4 | 15 | | | |
| MYLU | 2013 | | | | | | | 20.1 | 12.2 | 19.4 | | | |
| MYLU | 2014 | | | | | | 12.8 | 14.5 | 20.6 | 12.5 | | | |
| MYVO | 2014 | | | | | 5.5 | | | | | | | |

[1] Temperatures should only be regarded as being indicative of the general temperature at the time of detection. Temperatures were recorded at the detector approximately 1 meter above ground level while microphones were mounted at approximately 3 meters above ground level and bats were in flight at an unknown altitude, but probably typically within 30 meters of ground level. Temperatures of the bat's roost environment at the time flights were initiated are also obviously unknown.

[2] Species codes are the first two letters of the genus and species names.

**Table 16.** Minimum bat pass temperatures recorded for definitive call sequences of species across the detector network and at the Landusky detectors [1]

| Species | Minimum Temperature Recorded (°C) Across Network [2] | Minimum Temperature Recorded (°C) at Landusky Detectors [3] |
|---|---|---|
| Pallid Bat (*Antrozous pallidus*) | 5.2 | na |
| Townsend's Big-eared Bat (*Corynorhinus townsendii*) | 6.0 | 22.4 |
| Big Brown Bat (*Eptesicus fuscus*) | -4.8 | 3.2 |
| Spotted Bat (*Euderma maculatum*) | 1.9 | 13.8 |
| Eastern Red Bat (*Lasiurus borealis*) | 1.6 | 9.4 |
| Hoary Bat (*Lasiurus cinereus*) | -0.6 | 7.4 |
| Silver-haired Bat (*Lasionycteris noctivagans*) | -4.9 | 4.9 |
| California Myotis (*Myotis californicus*) | -0.5 | na |
| Western Small-footed Myotis (*Myotis ciliolabrum*) | -4.8 | 10.8 |
| Long-eared Myotis (*Myotis evotis*) | -2.1 | 8.4 |
| Little Brown Myotis (*Myotis lucifugus*) | -0.5 | 7.0 |
| Fringed Myotis (*Myotis thysanodes*) | 3.1 | na |
| Long-legged Myotis (*Myotis volans*) | 5.5 | 5.5 |
| Yuma Myotis (*Myotis yumanensis*) | 6.7 | na |

[1] Temperatures should only be regarded as being indicative of the general temperature at the time of detection. Temperatures were recorded at the detector approximately 1 meter above ground level while microphones were mounted at approximately 3 meters above ground level and bats were in flight at an unknown altitude, but probably typically within 30 meters of ground level. Temperatures of the bat's roost environment at the time flights were initiated are also obviously unknown.

[2] Probable call sequences of Western Small-footed Myotis (-8.6 °C), Big Brown Bat (-8.4°C), Silver-haired Bat (-7.4°C), Long-eared Myotis (-2.9°C), and Hoary Bat (-2°C) were also recorded.

[3] Probable call sequences of Western Small-footed Myotis (1.7 °C), Big Brown Bat or Silver-haired Bat (1.3°C), Silver-haired Bat (-7.4°C), and Little Brown Myotis (3.1°C) were also recorded. na = outside species' range.

**Table 17.** Wind speed from anemometer on ridge where wind turbine was installed between 9 November 2005 and 22 August 2010. Yearly summaries are in bolded/shaded rows.

| Year | Mean Wind Speed (m/s) | SD Wind Speed (m/s) | N |
|---|---|---|---|
| **2005** | **7.3** | **4.0** | **7575** |
| Nov | 7.2 | 4.1 | 3111 |
| Dec | 7.4 | 4.0 | 4464 |
| **2006** | **6.8** | **3.9** | **31546** |
| Jan | 7.0 | 3.6 | 4464 |
| Feb | 6.4 | 3.1 | 4032 |
| Mar | 6.1 | 3.4 | 4464 |
| Apr | 5.1 | 3.2 | 635 |
| Aug | 8.4 | 4.1 | 383 |
| Sep | 6.6 | 3.7 | 4320 |
| Oct | 7.0 | 4.1 | 4464 |
| Nov | 7.0 | 4.0 | 4320 |
| Dec | 7.7 | 4.9 | 4464 |
| **2007** | **7.3** | **4.2** | **34978** |
| Jan | 9.3 | 4.8 | 4464 |
| Feb | 6.7 | 5.1 | 4032 |
| Mar | 7.3 | 4.1 | 4464 |
| Apr | 6.3 | 3.7 | 4320 |
| May | 6.6 | 3.3 | 4464 |
| Jun | 6.9 | 3.8 | 4320 |
| Jul | 8.1 | 3.8 | 4464 |
| Aug | 7.2 | 4.0 | 4450 |
| **2008** | **6.5** | **3.7** | **18049** |
| Aug | 7.7 | 4.0 | 481 |
| Sep | 5.1 | 2.9 | 4320 |
| Oct | 6.7 | 3.4 | 4464 |
| Nov | 7.2 | 3.8 | 4320 |
| Dec | 7.0 | 4.1 | 4464 |
| **2009** | **6.7** | **4.0** | **25553** |
| Jan | 5.7 | 3.4 | 2851 |
| Jul | 6.2 | 3.4 | 670 |
| Aug | 6.1 | 3.2 | 4464 |
| Sep | 7.2 | 4.1 | 4320 |
| Oct | 7.5 | 4.5 | 4464 |
| Nov | 6.9 | 3.5 | 4320 |
| Dec | 6.3 | 4.5 | 4464 |
| **2010** | **6.3** | **4.0** | **33574** |
| Jan | 5.9 | 4.3 | 4464 |
| Feb | 4.9 | 3.5 | 4032 |
| Mar | 6.0 | 3.7 | 4464 |
| Apr | 8.5 | 4.6 | 4320 |
| May | 7.8 | 4.5 | 4464 |
| Jun | 6.1 | 3.5 | 4320 |
| Jul | 5.6 | 3.2 | 4464 |
| Aug | 5.8 | 2.8 | 3046 |
| **Grand Total** | **6.8** | **4.0** | **151277** |

**Figure 1.** Network of long term ultrasonic acoustic detectors as of fall 2015

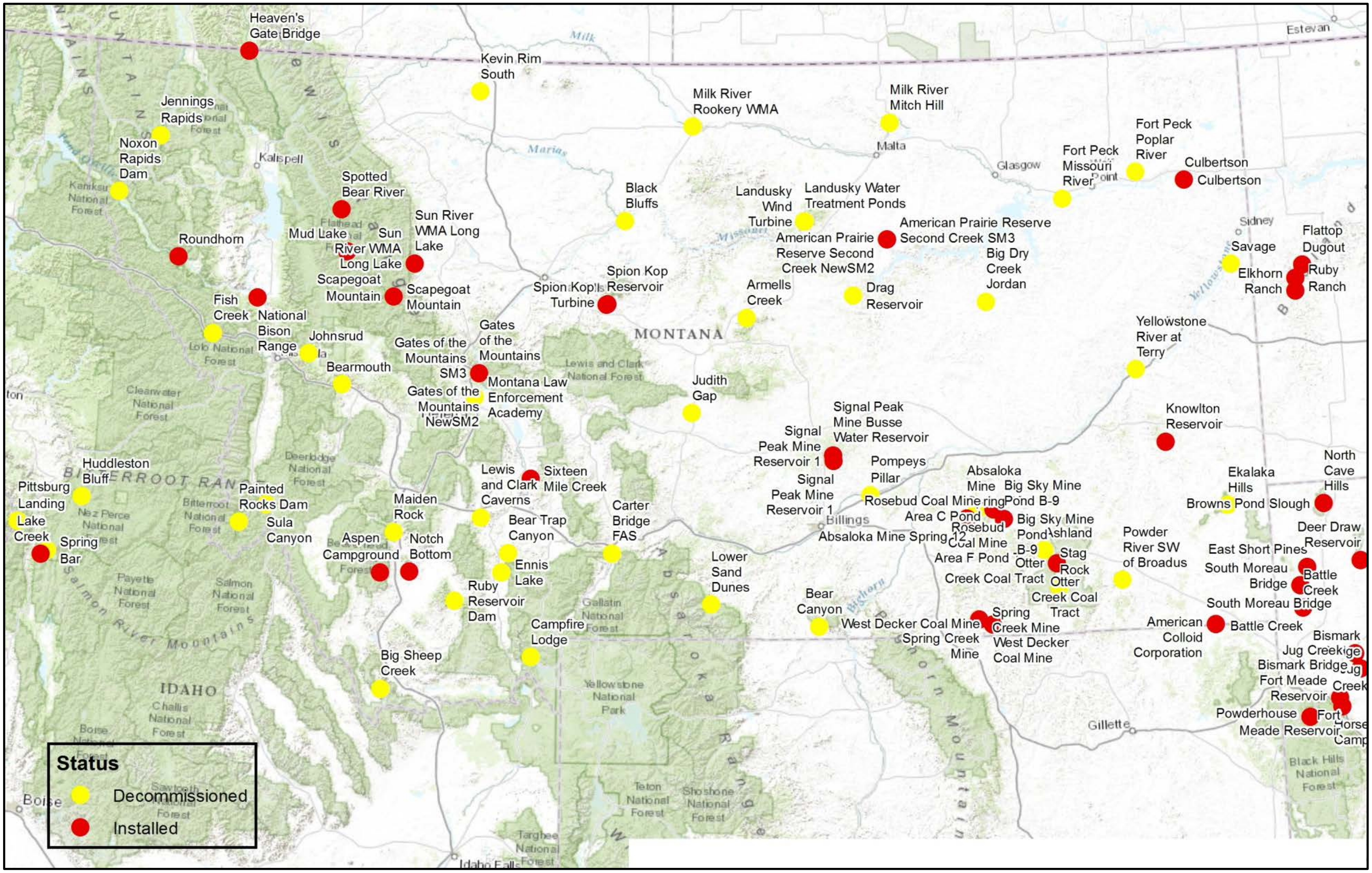


**Figure 2a.** Little Rocky Mountains with location of Landusky wind turbine (red x), Zortman weather station (red circle), and Hays weather station (red square), and Azure Cave (red star), Montana's largest known bat hibernaculum

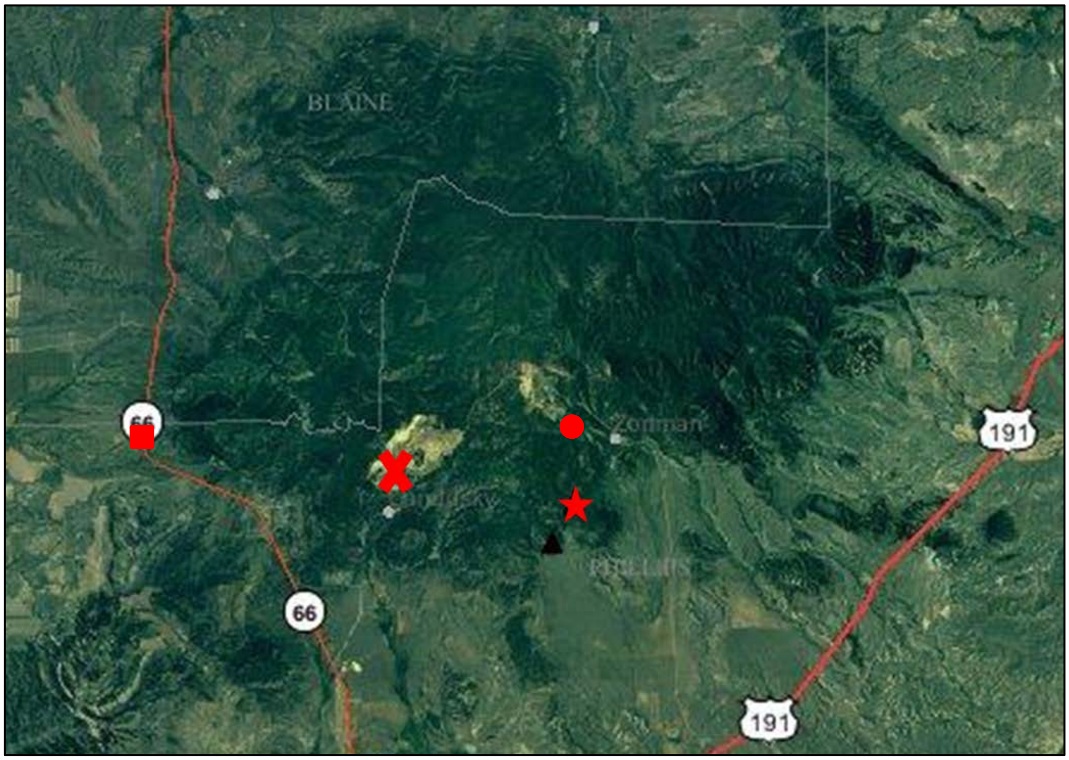



**Figure 2b.** Location of Landusky wind turbine (red +) and water treatment and wind turbine bat detectors (red stars)

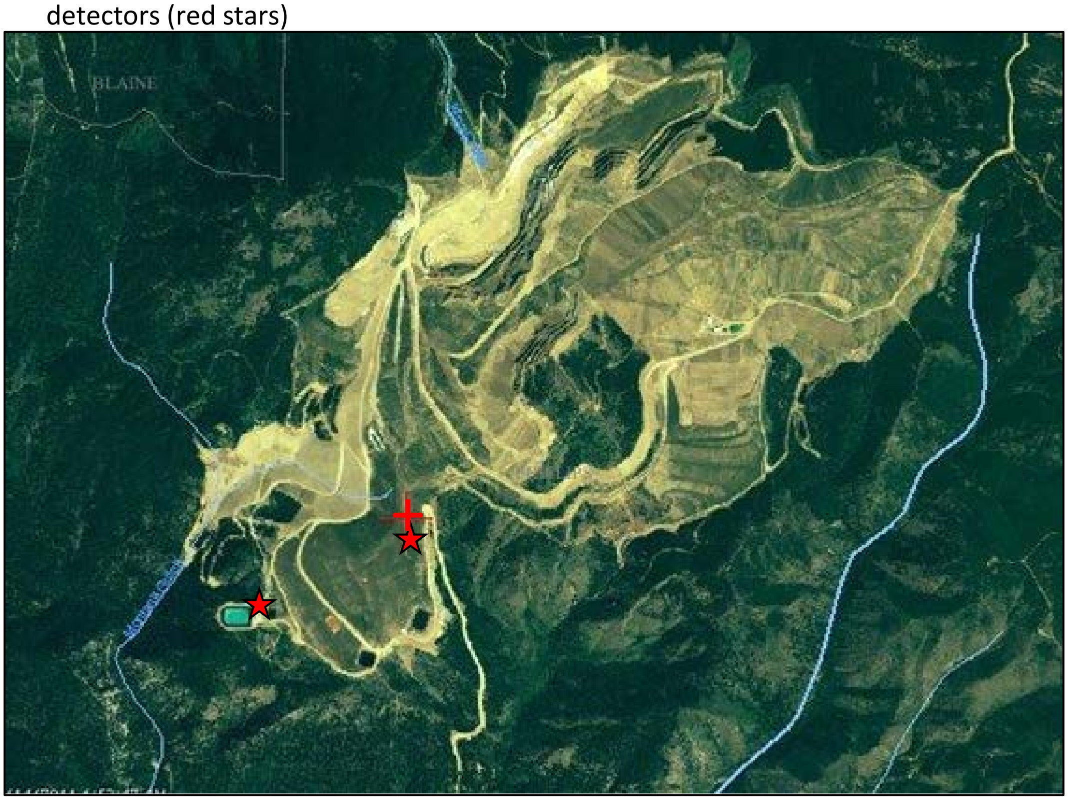
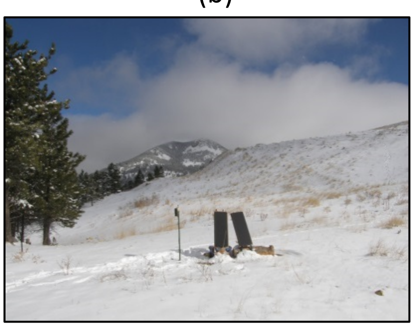


**Figure 3a.** Overview of bat detector near the Landusky water treatment facility. SM2 Bat detector/recorder (square) and microphones (stars) facing south-southwest

**Figures 3b-d.** Bat detector and microphone locations near water treatment facility. Solar panels and SM2 Bat detector/recorder facing north (b), microphone location (star) on rainwater pond facing southeast (c), and microphone location near the water treatment pond facing southwest

(b)



(c)

(d)

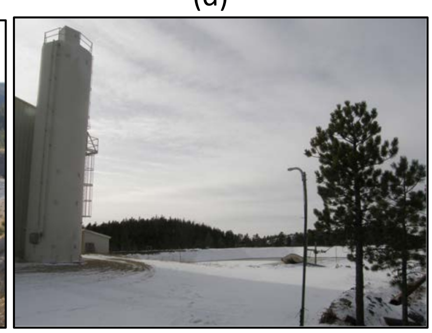
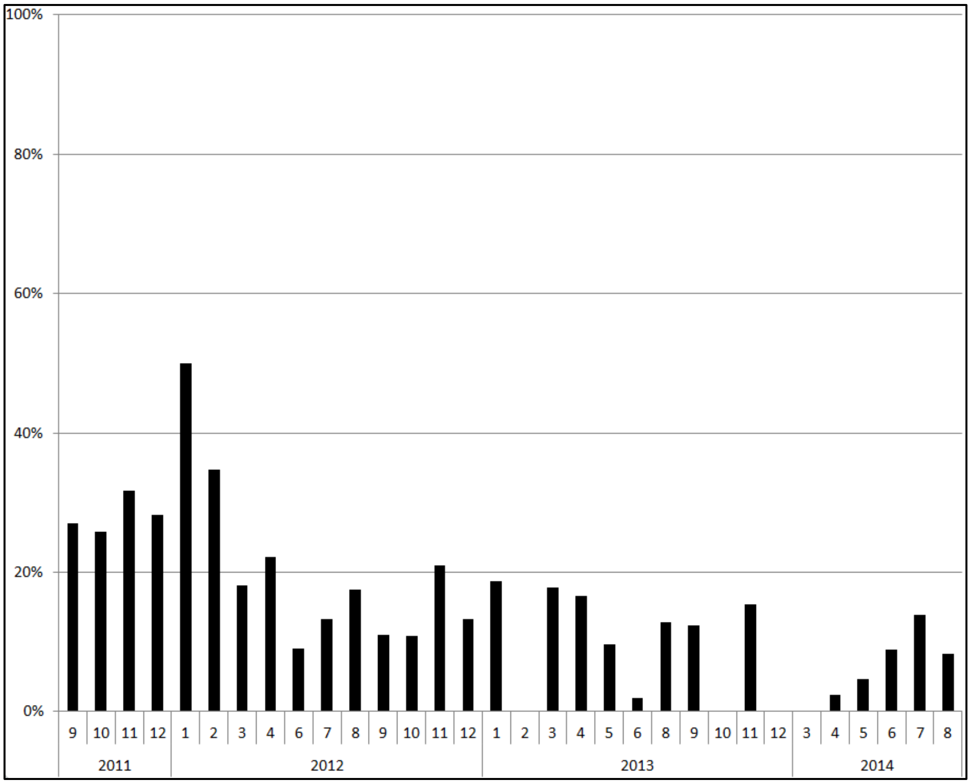


**Figure 4.** SM2Bat+ detector/recorder and microphone deployed near Landusky wind turbine

**Figure 5.** Percent of call sequences auto-identified to species each month at water treatment ponds (a) and wind turbine (b). Numbers on X axis are years and months.

(a)




(b)

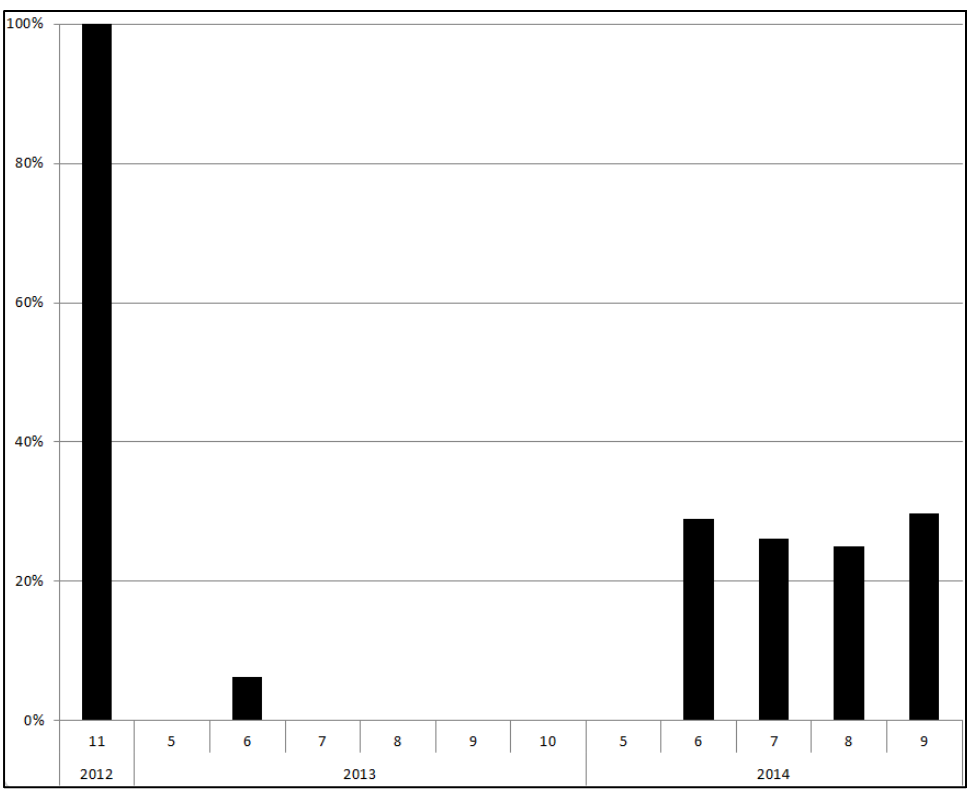
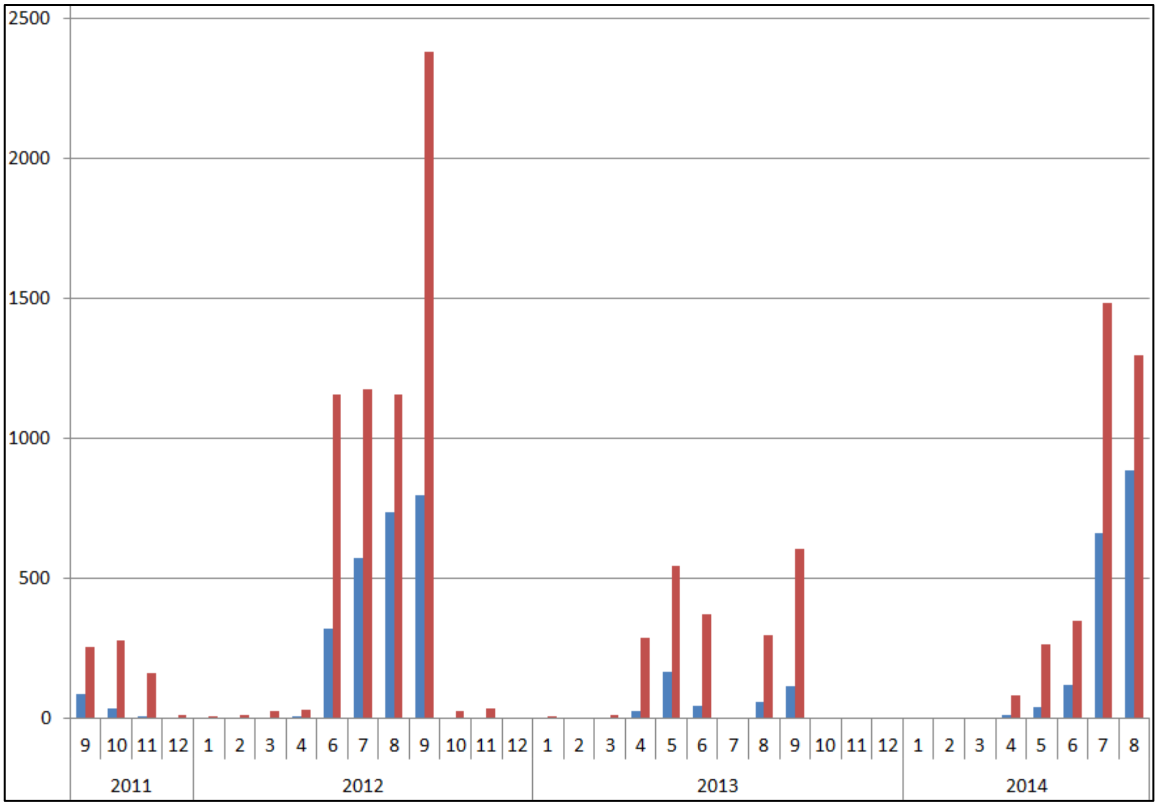


**Figure 6.** Average (blue) and maximum counts (red) of bat passes per night by month for water treatment ponds (a) and wind turbine (b). Numbers on X axis are years and months.

(a)




(b)

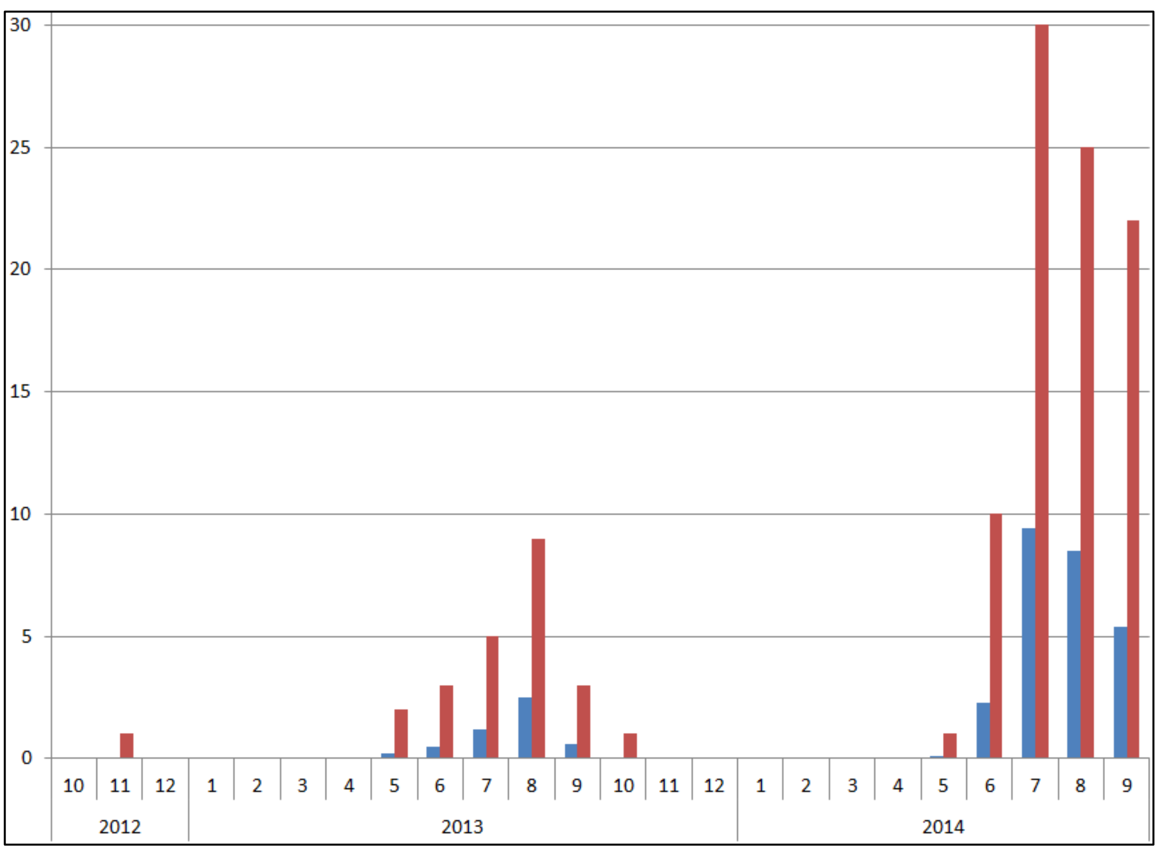
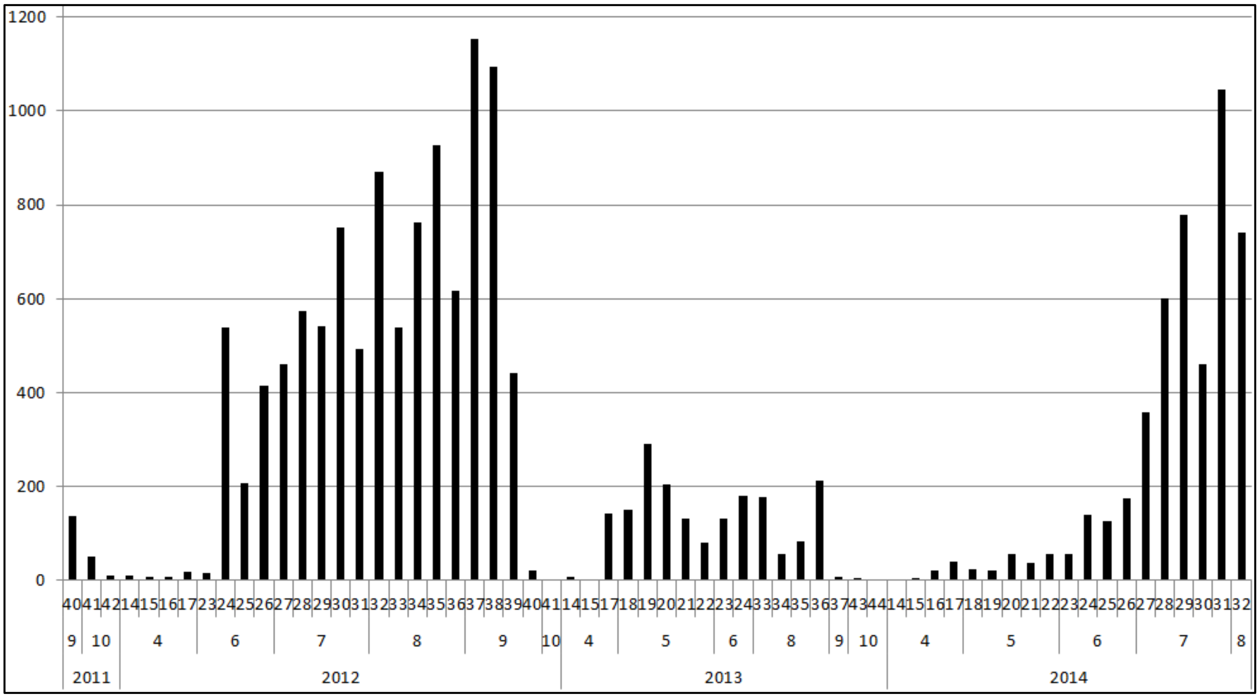


**Figure 7.** Average number of bat passes per night by week at water treatment ponds for active season (a) and inactive season (b). Numbers on X axis are years, months, and weeks.

(a)




(b)

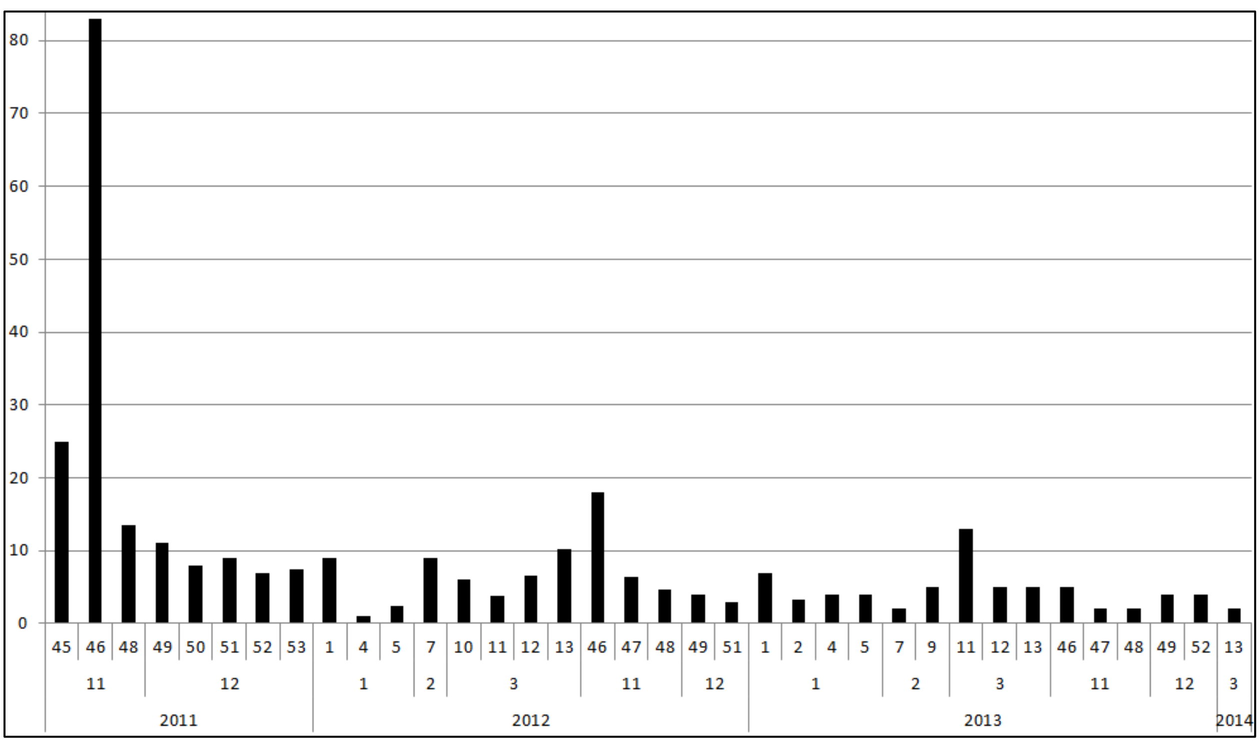


**Figure 8.** Average number of bat passes per night by week at wind turbine for active season. Numbers on X axis are years, months, and weeks. With the exception of single bat passes from an unidentified 30 kHz bat on 17 November of 2012 and 25 October 2013, no bat passes were recorded at the wind turbine between October and May.

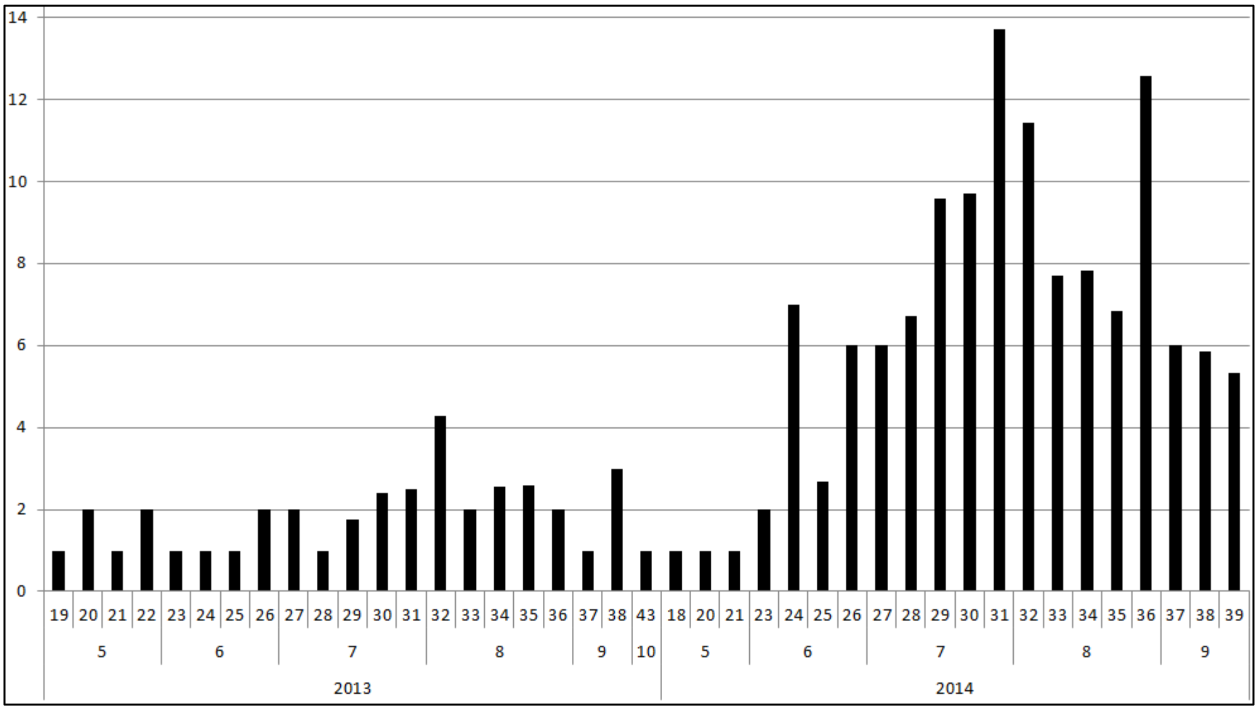
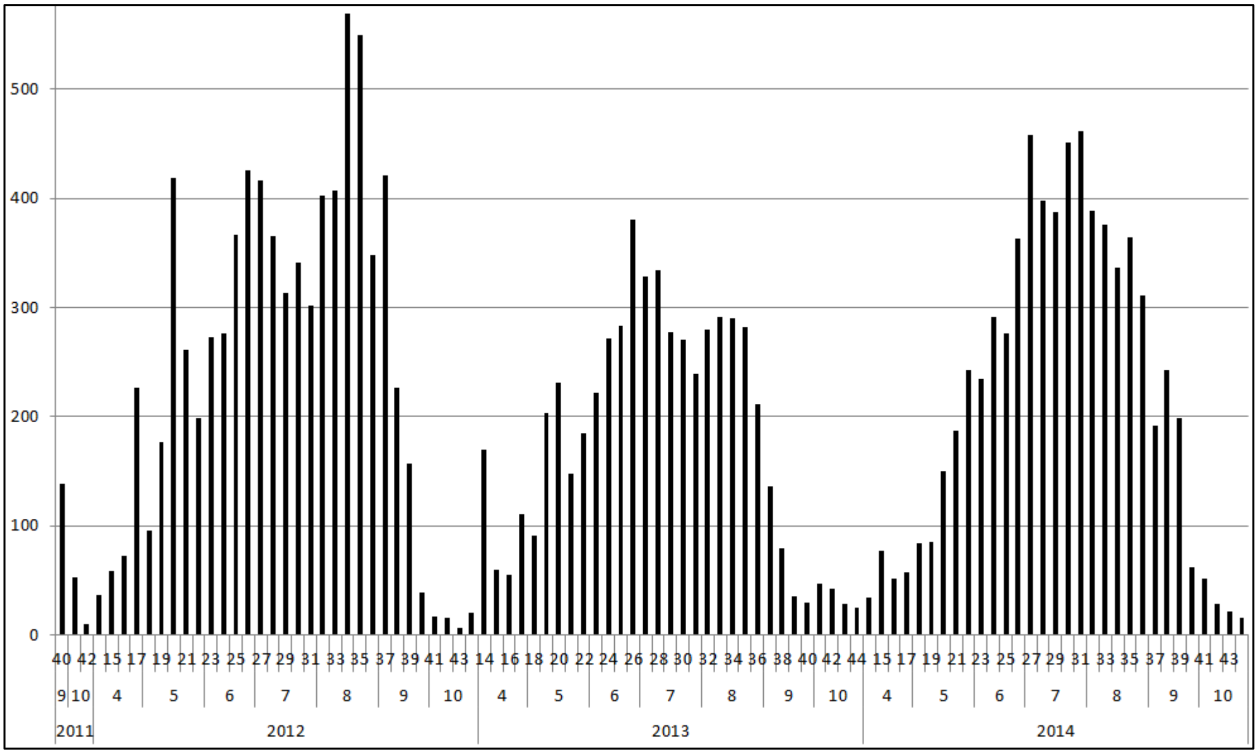


**Figure 9.** Average number of bat passes per night by week across the detector network for active season (a) and inactive season (b). Numbers on X axis are years, months, and weeks.

(a)



(b)

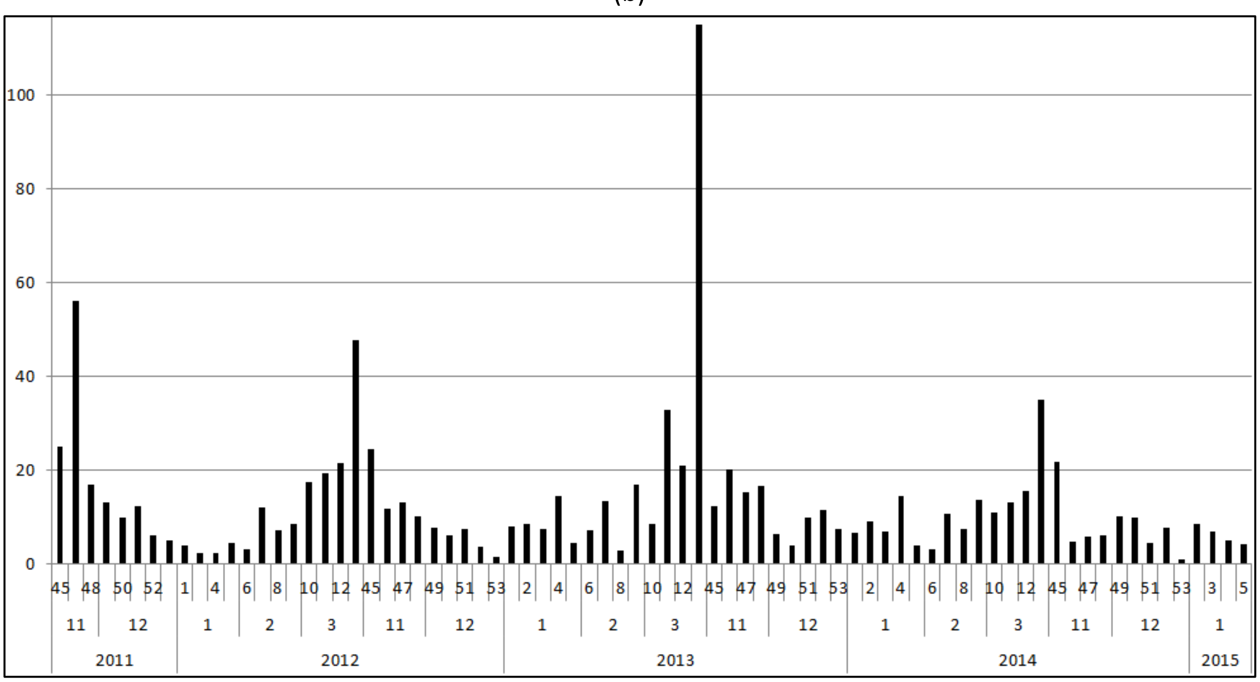
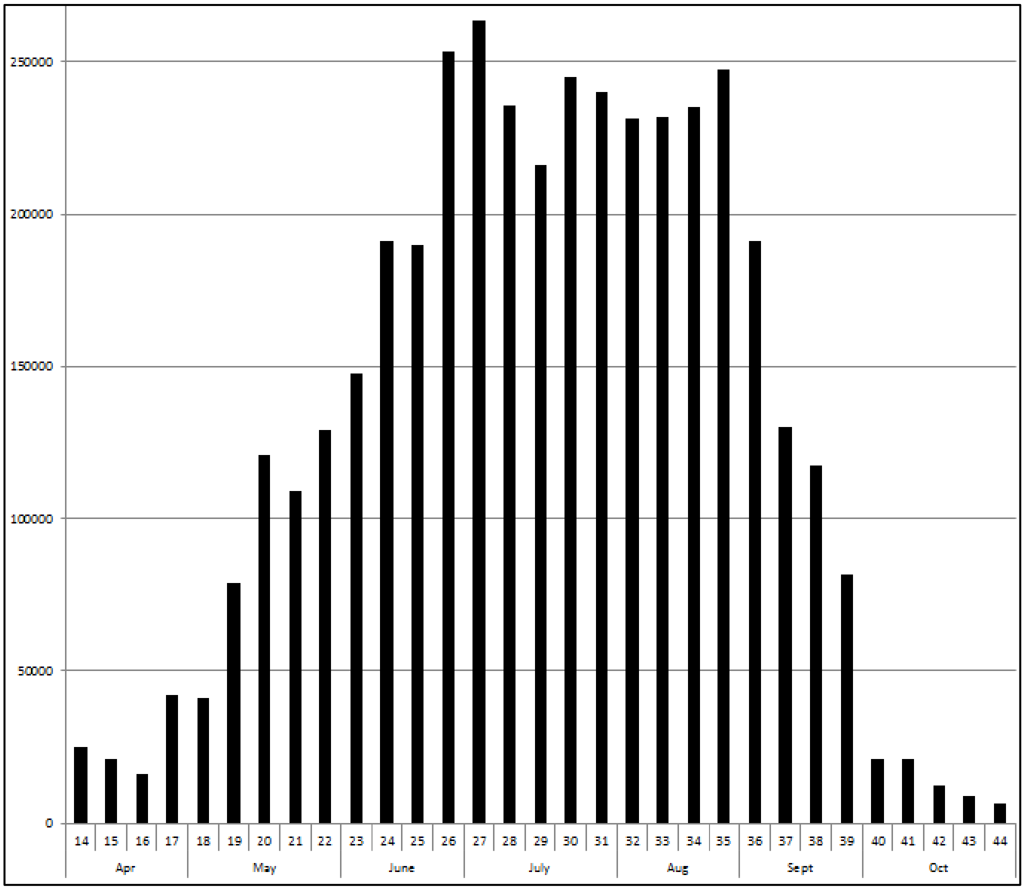


**Figure 10.** Total number of bat passes per night by week across the detector network and across all years for active season (a) and inactive season (b) as of fall 2015.

(a)




(b)

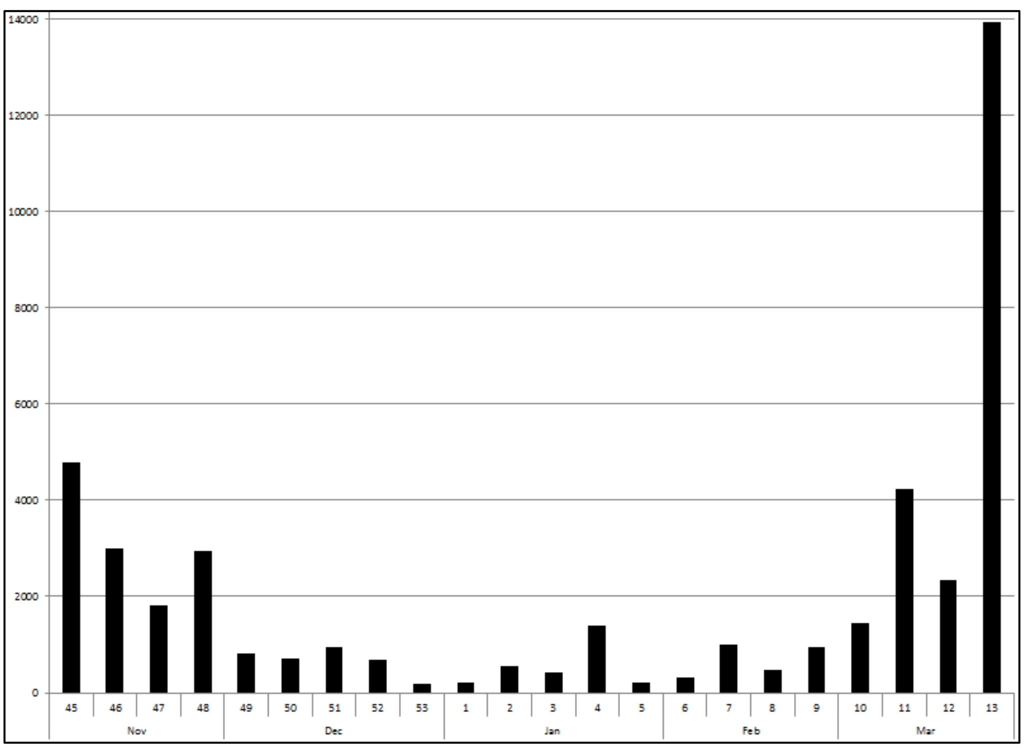
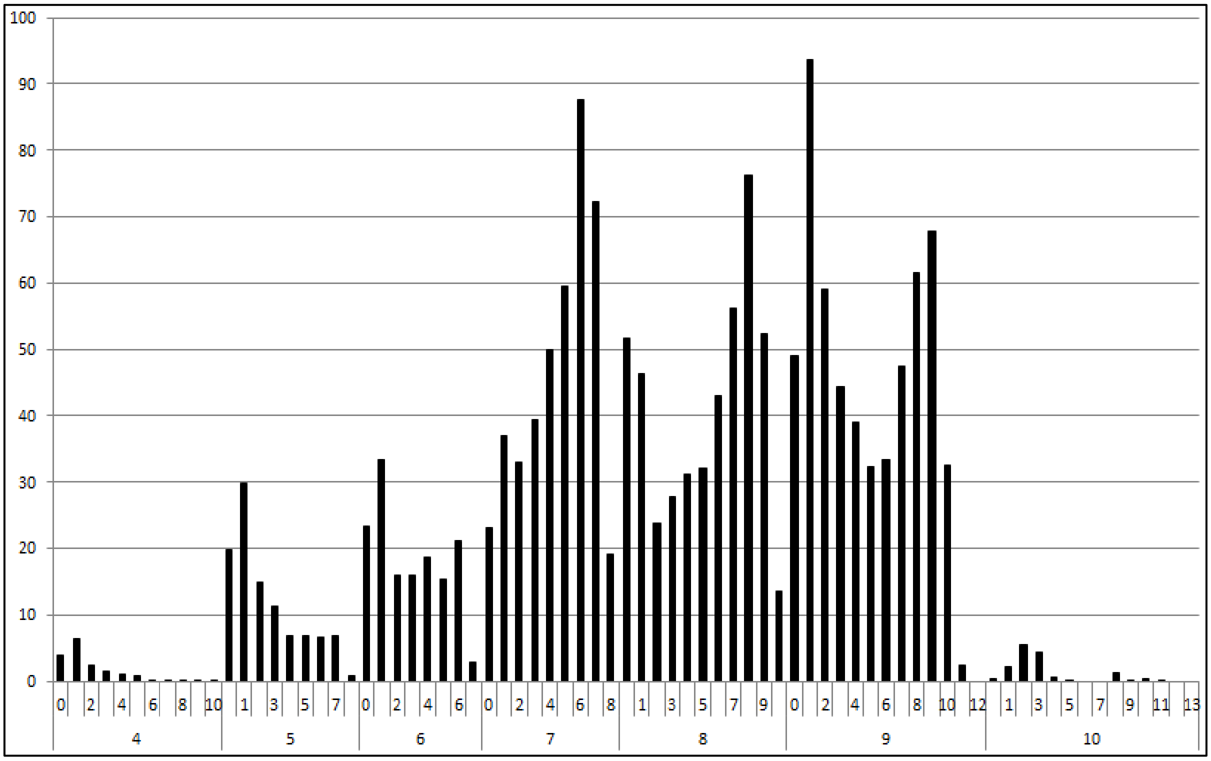


**Figure 11.** Average number of bat passes each hour after sunset across all years for water treatment ponds during active (a) and inactive season (b). Numbers on X axis are months and weeks.

(a)




(b)

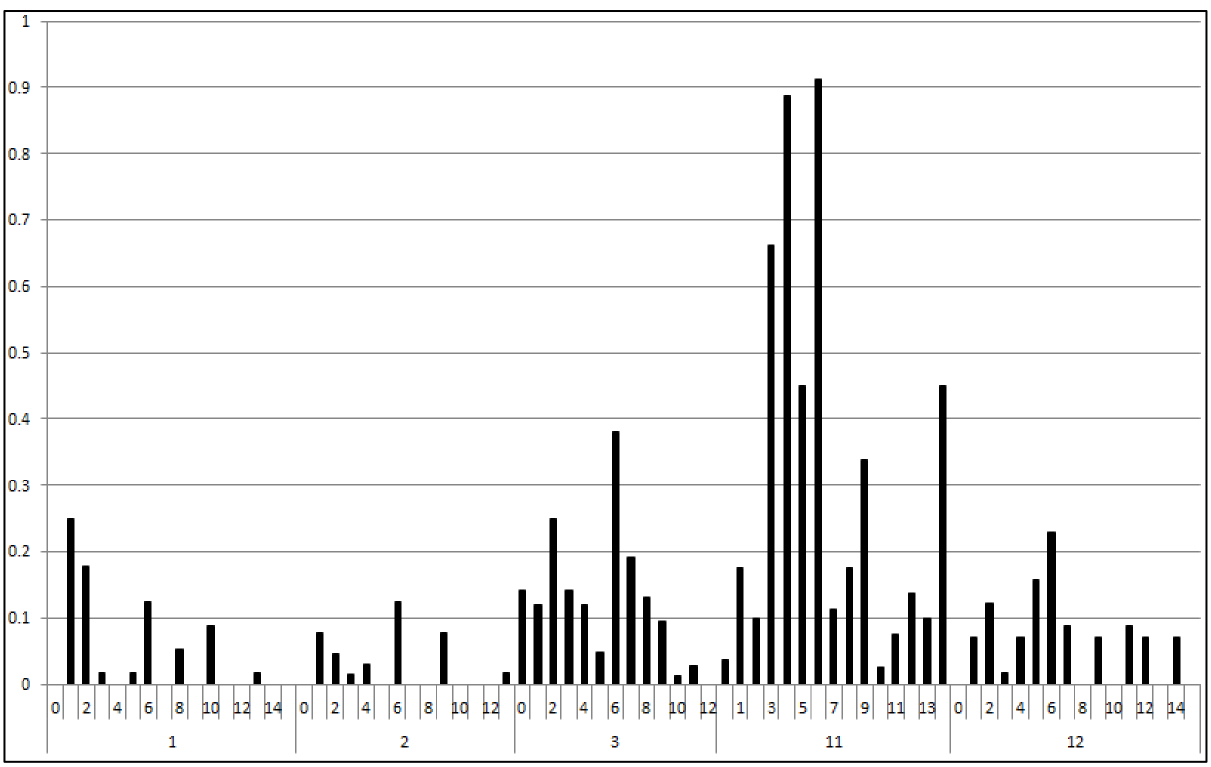
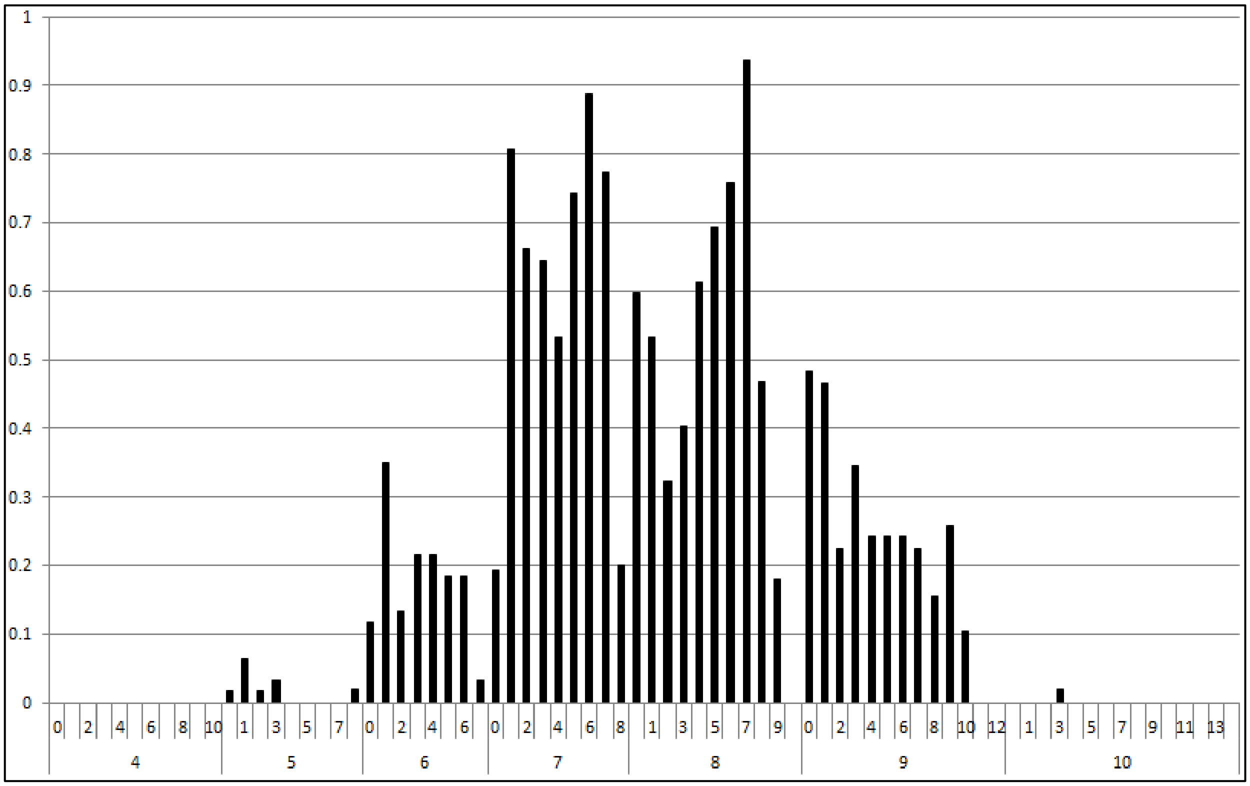


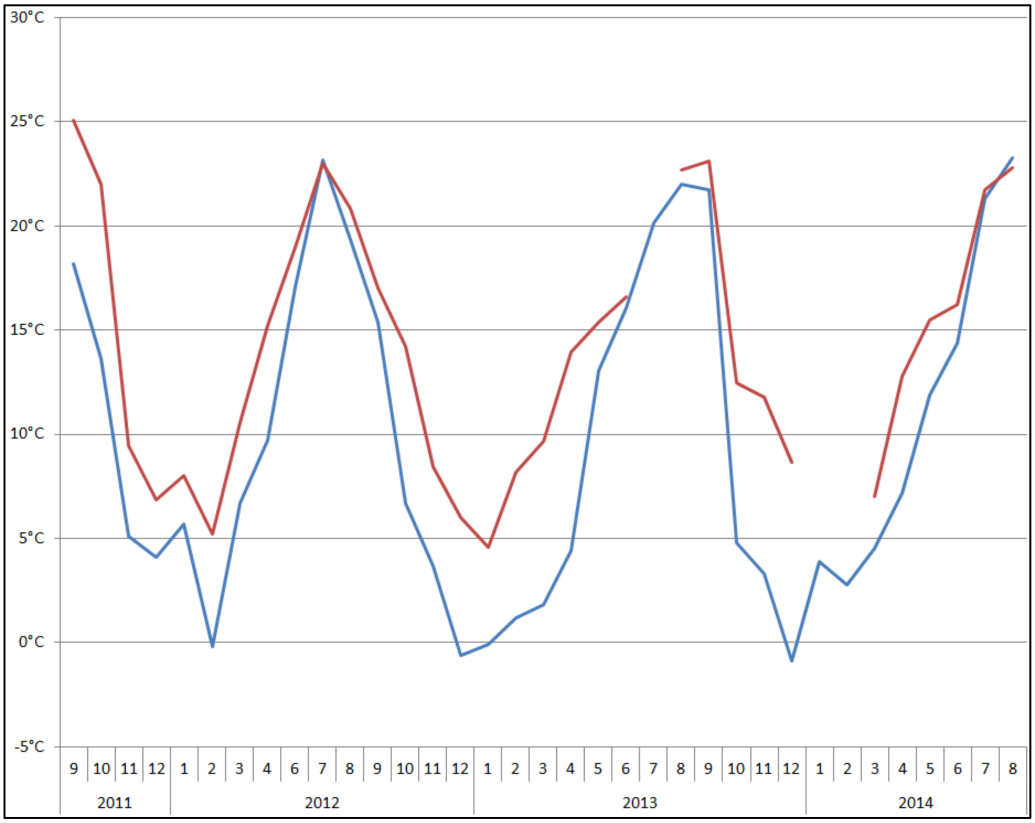
**Figure 12.** Average number of bat passes each hour after sunset across all years for wind turbine during active season [1]. Numbers on X axis are months and weeks.




[1] Only one bat pass was recorded at the wind turbine during the inactive season on 17 November 2012.

**Figure 13.** Average nightly background (blue) and bat pass (red) temperatures by month at water treatment ponds (a) and wind turbine (b). Numbers on X axis are years and months.

(a)




(b)

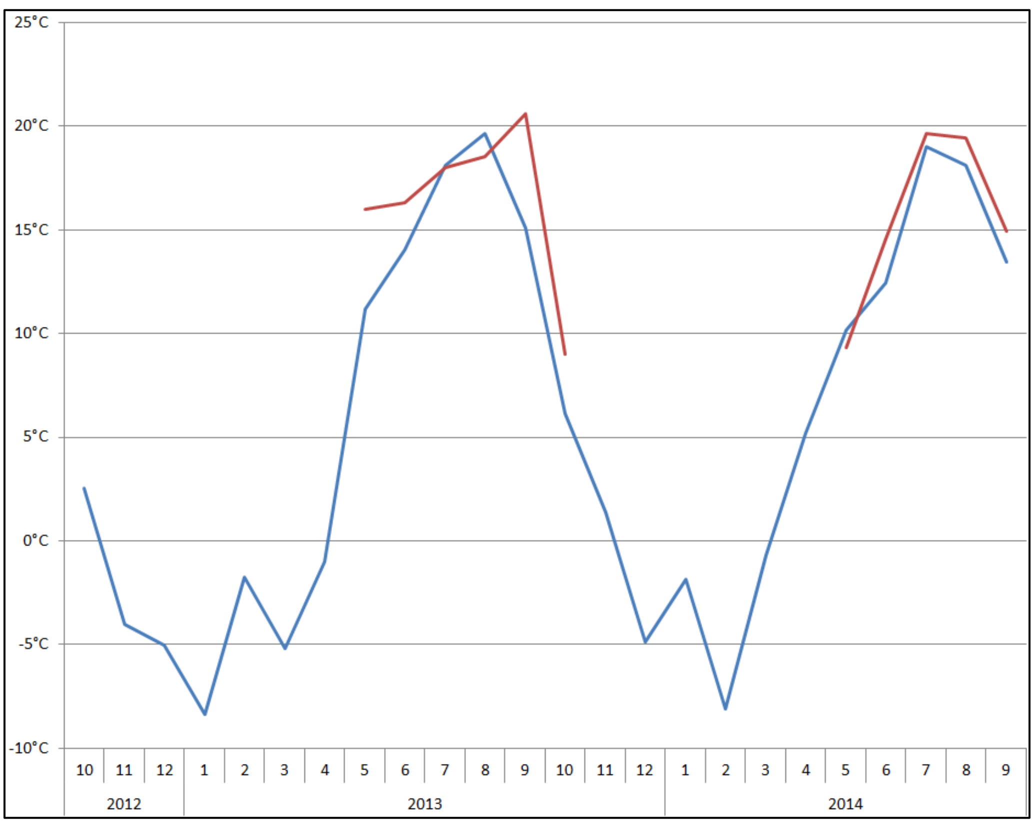


**Figure 14.** Percent of nightly hours with average background temperatures (blue) and average temperatures associated with bat passes (red) at the water treatment ponds (a) and wind turbine (b) for the Zortman weather station. Numbers are lower ends of °C temperature bins.

(a)

(b)

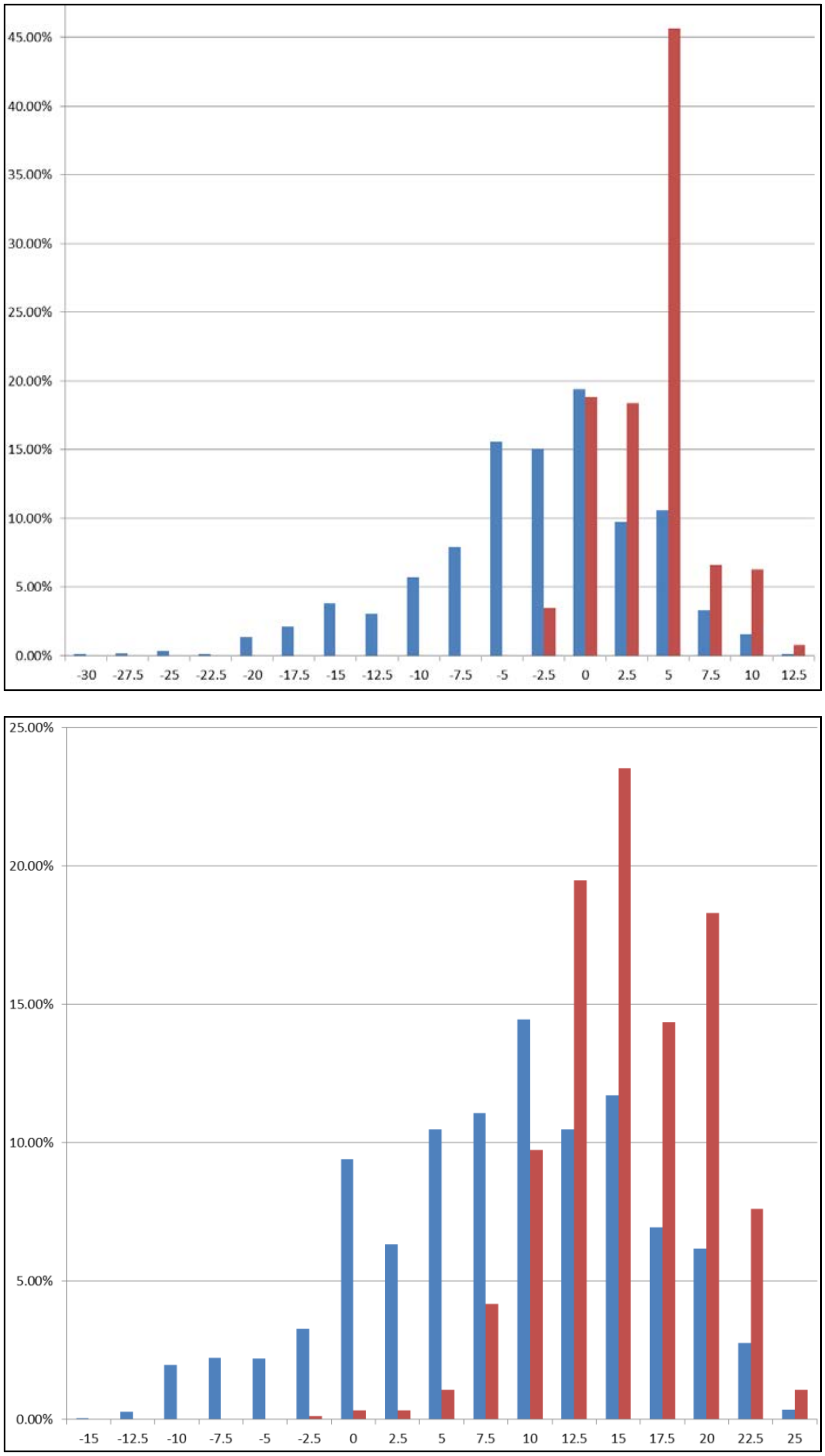


**Figure 15.** Percent of nightly hours with average background temperatures (blue) and average temperatures associated with bat passes (red) across the regional network of detectors. Numbers are lower ends of °C temperature bins. Of the 467,512 hours that detectors have been deployed, temperature data was available from nearby weather stations for 457,613 hours (98%). Note that some detectors were up to 43 kilometers from the weather station where temperatures were recorded (X = 14.9 km, SD = 10.3 km).

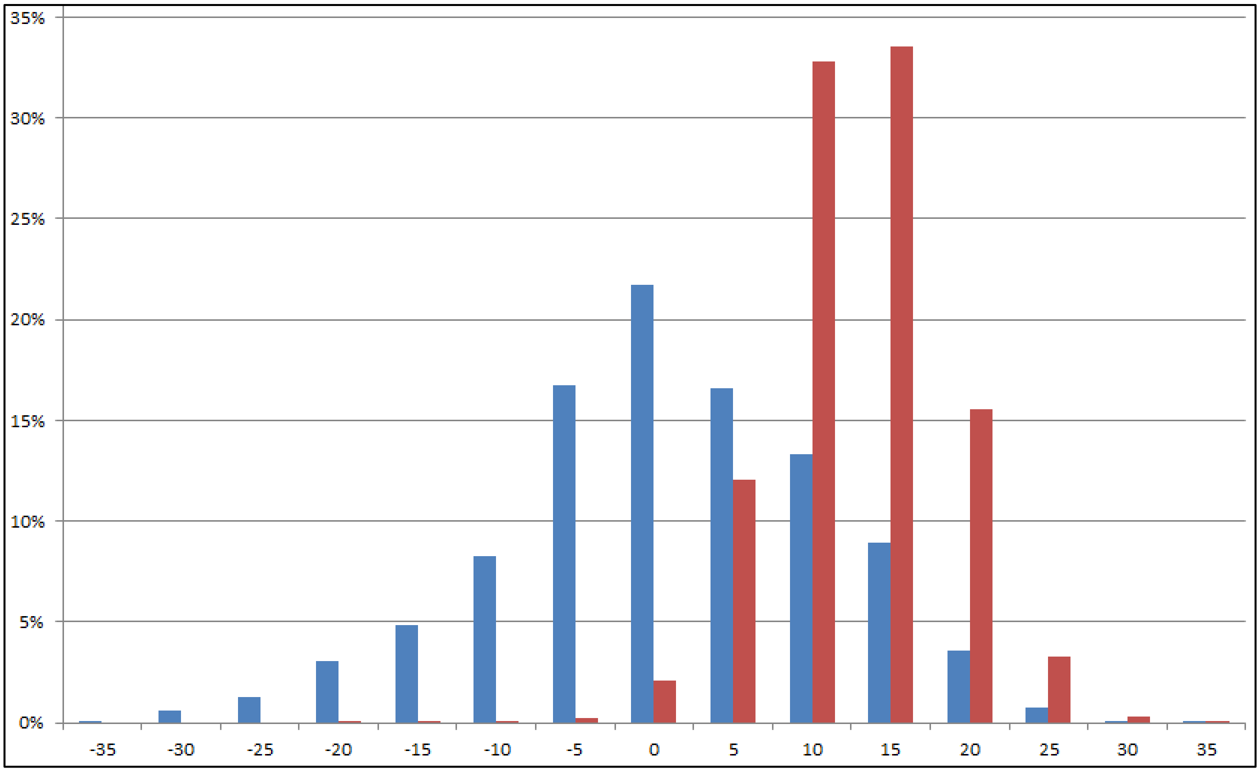
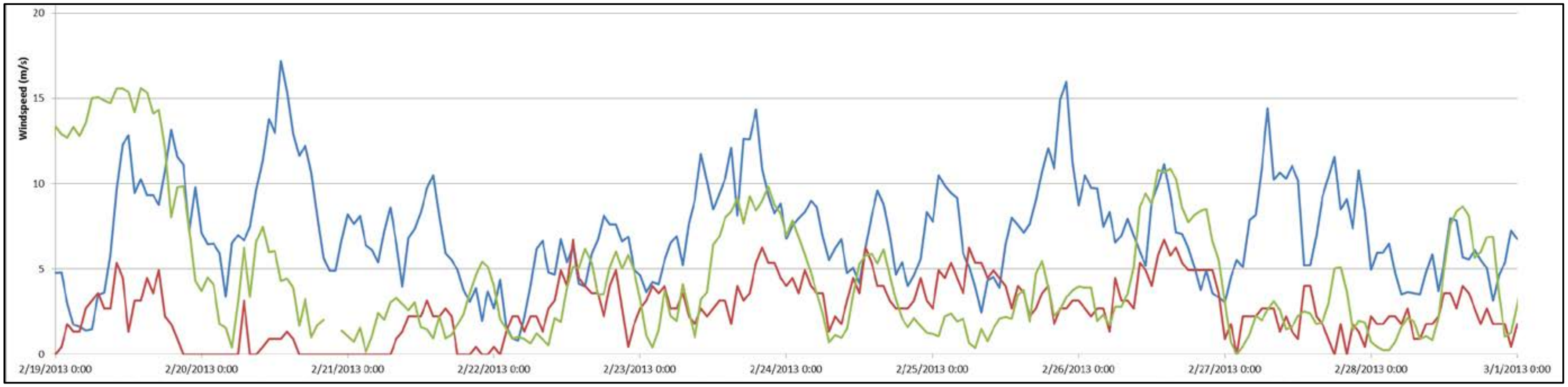
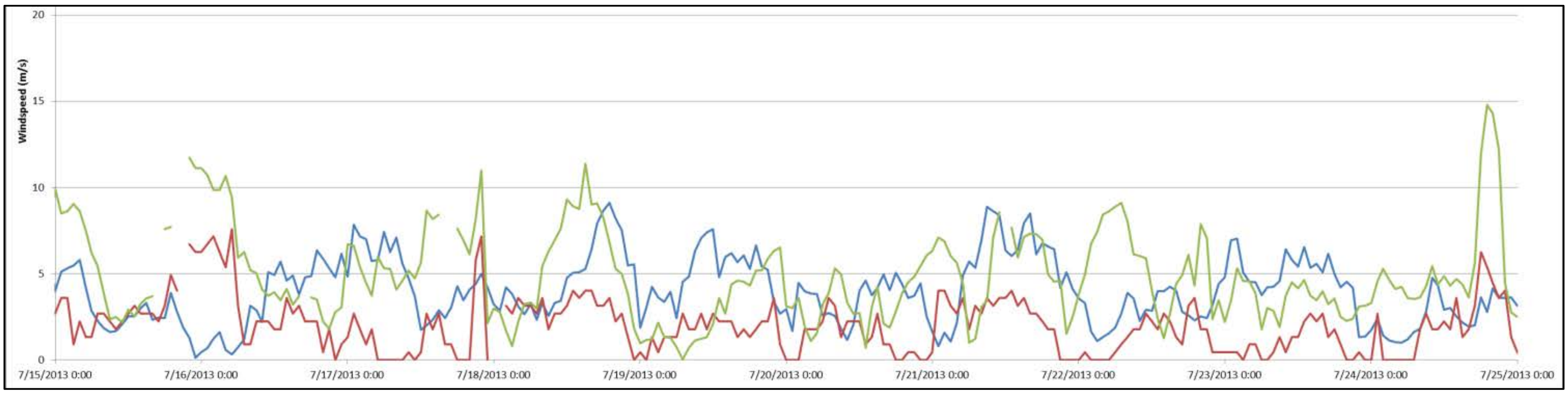


**Figure 16.** Example comparisons of wind speed (m/s) patterns at the Zortman (red) and Hays (green) weather stations and at the nacelle of the Landusky wind turbine (blue) for February of 2013 (a), July of 2013 (b), and May of 2014 (c)

(a)




(b)




(c)

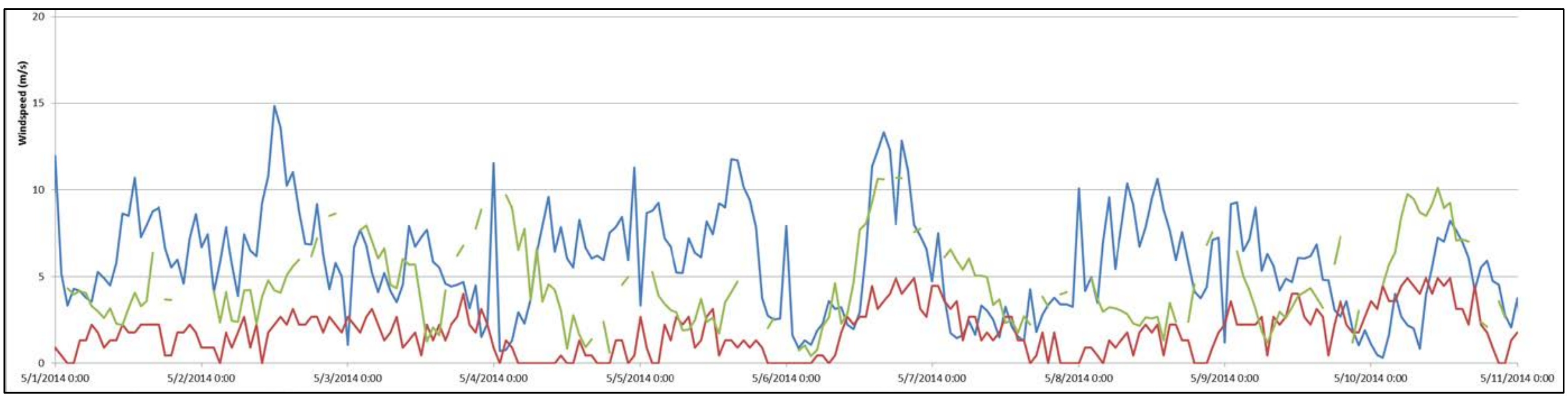


**Figure 17.** Counts of hourly averages of wind bearings at the Hays (a), and Zortman (b) weather stations from 1 October 2011 to 30 September 2014, and on the ridgeline where the wind turbine was eventually installed from 9 November 2005 to 22 August 2010. Wind direction from the anemometer on the turbine was not available.

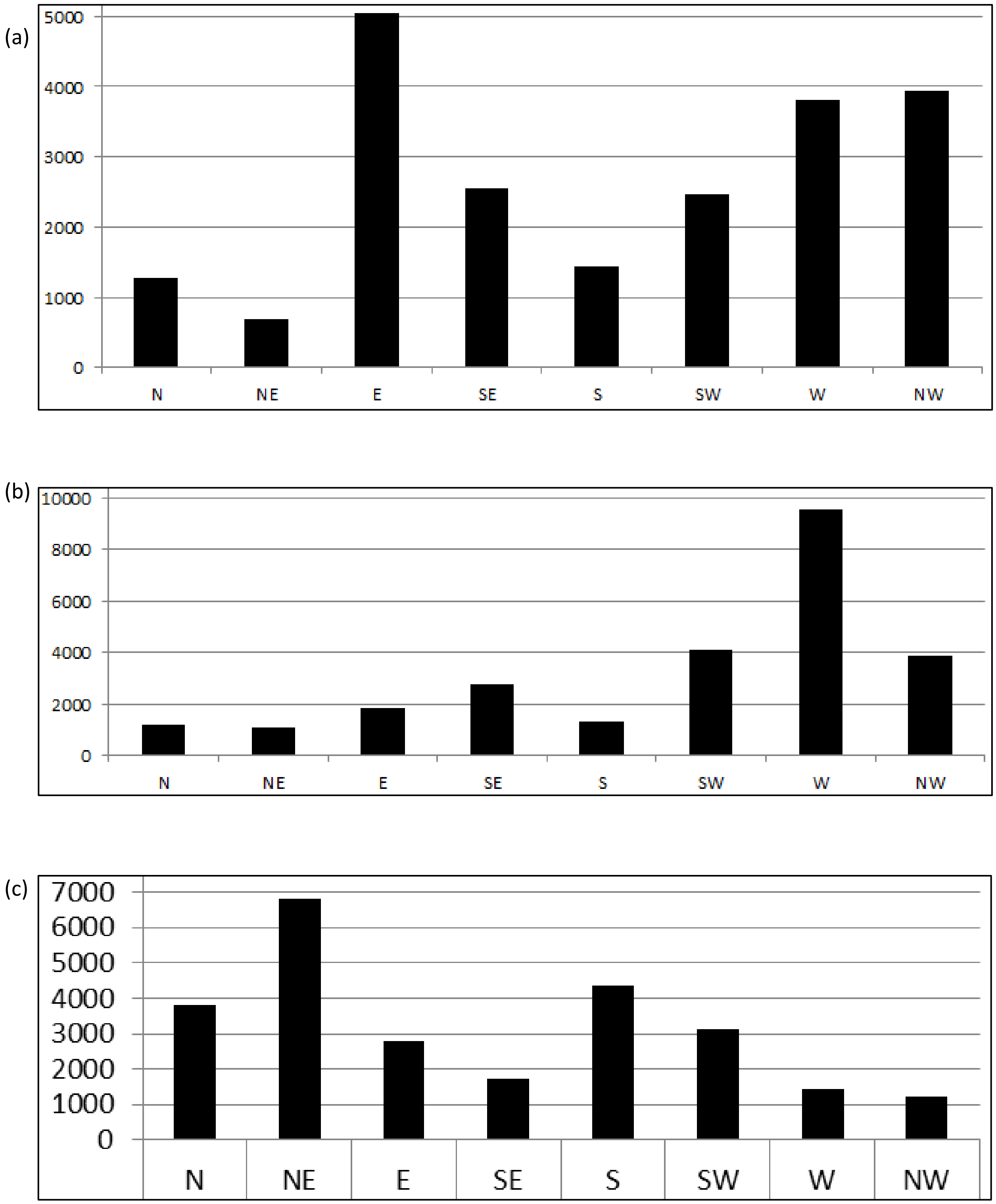
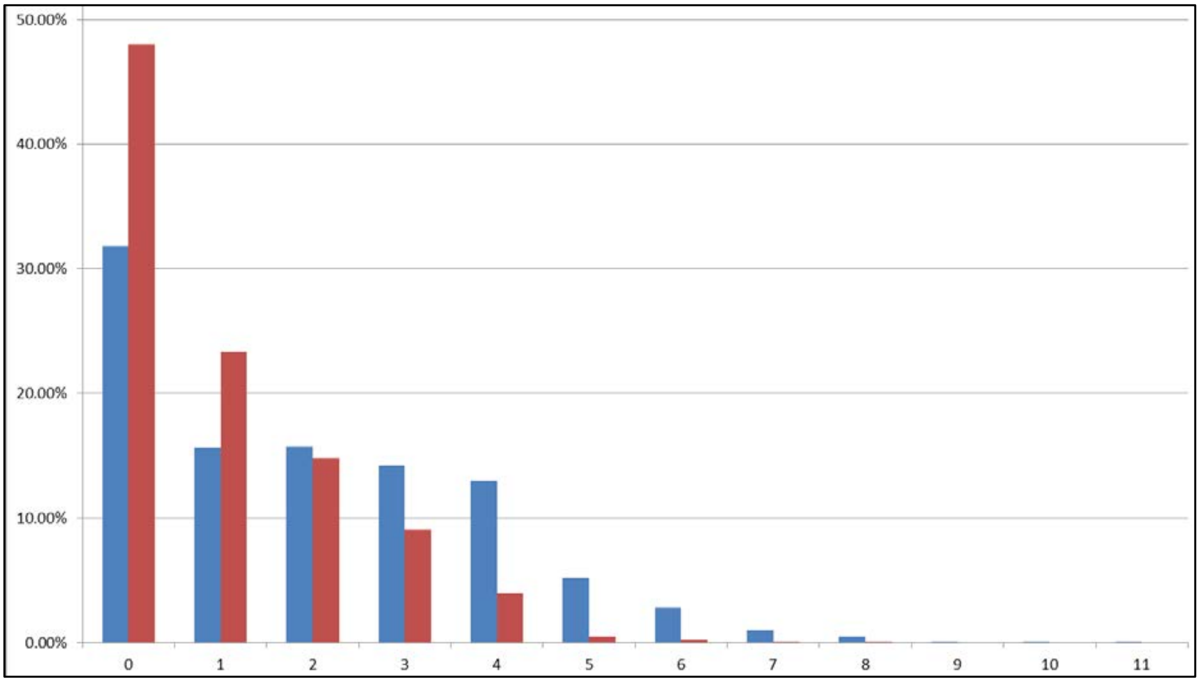


**Figure 18.** Percent of hours with average background wind speeds (blue) and average wind speeds associated with bat passes (red) for the water treatment ponds (a) and wind turbine (b) at the Zortman weather station. Wind speed categories are meters per second.

(a)




(b)

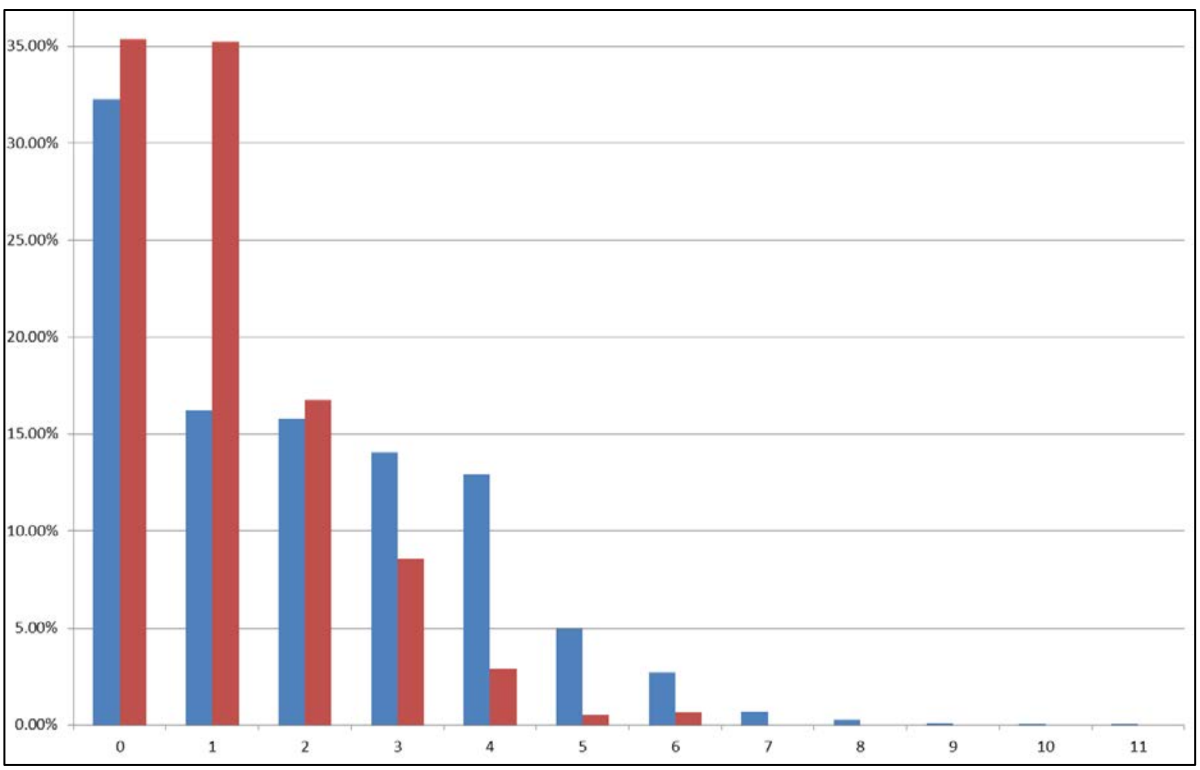
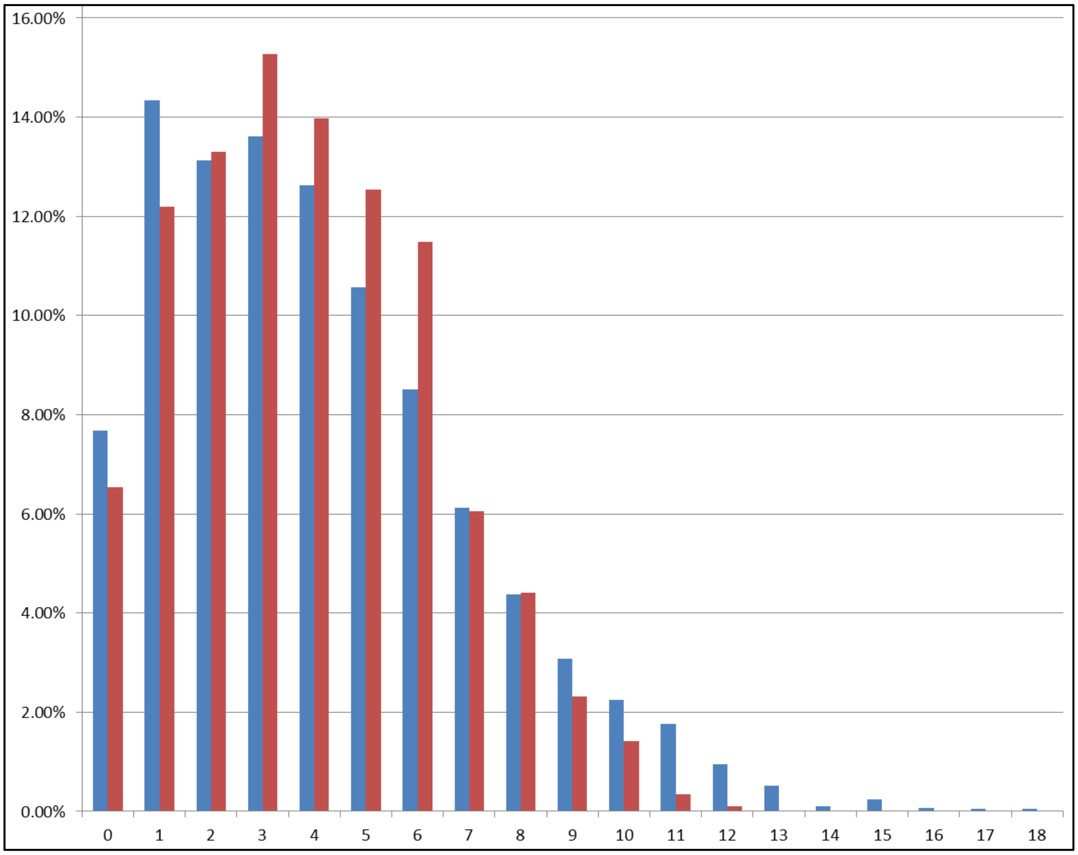


**Figure 19.** Percent of hours with average background wind speeds (blue) and average wind speeds associated with bat passes (red) for the water treatment ponds (a) and wind turbine (b) at the Hays weather station. Wind speed categories are meters per second.

(a)




(b)

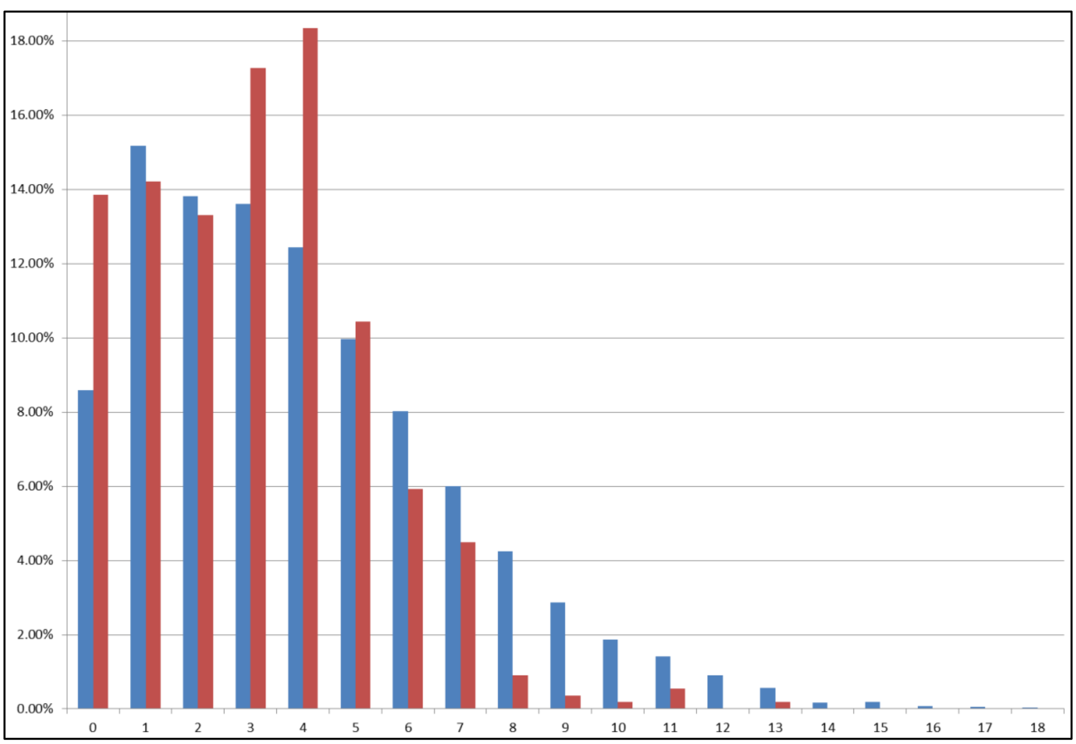
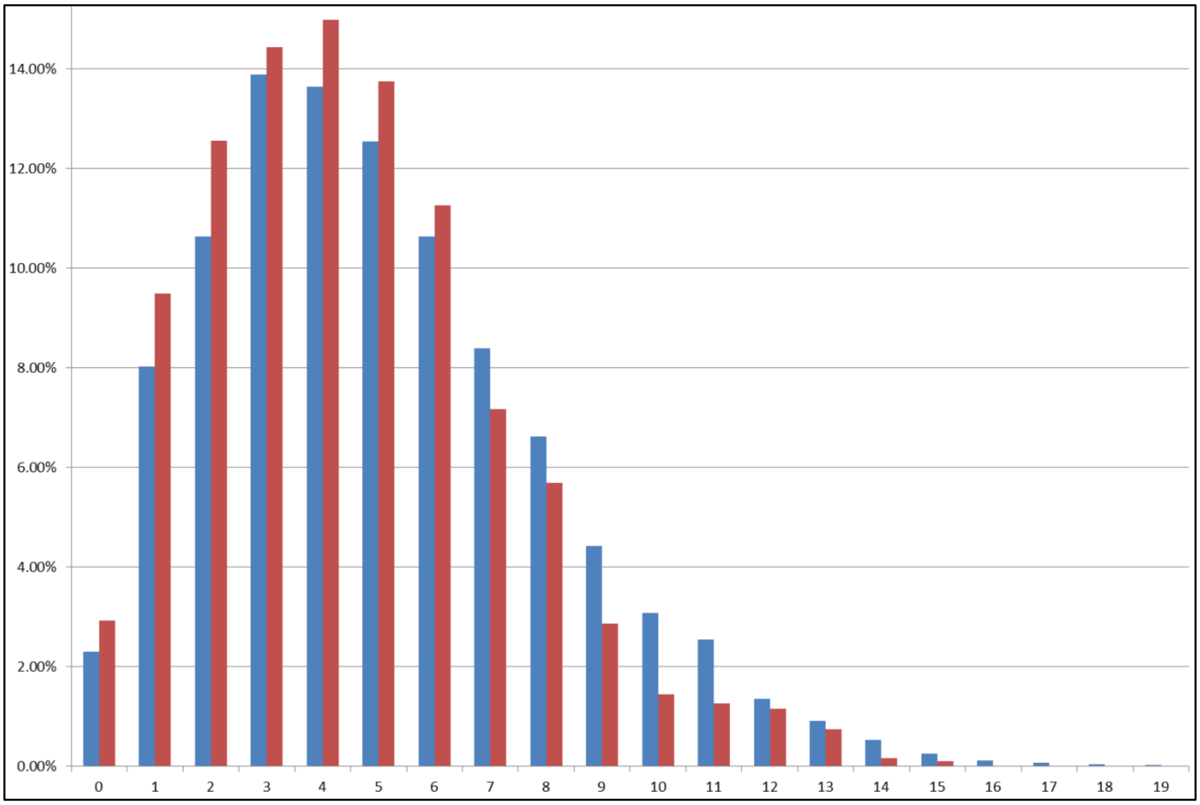


**Figure 20.** Percent of hours with average background wind speeds (blue) and average wind speeds associated with bat passes (red) for the water treatment ponds (a) and wind turbine (b) at the wind turbine nacelle. Wind speed categories are meters per second.

(a)




(b)

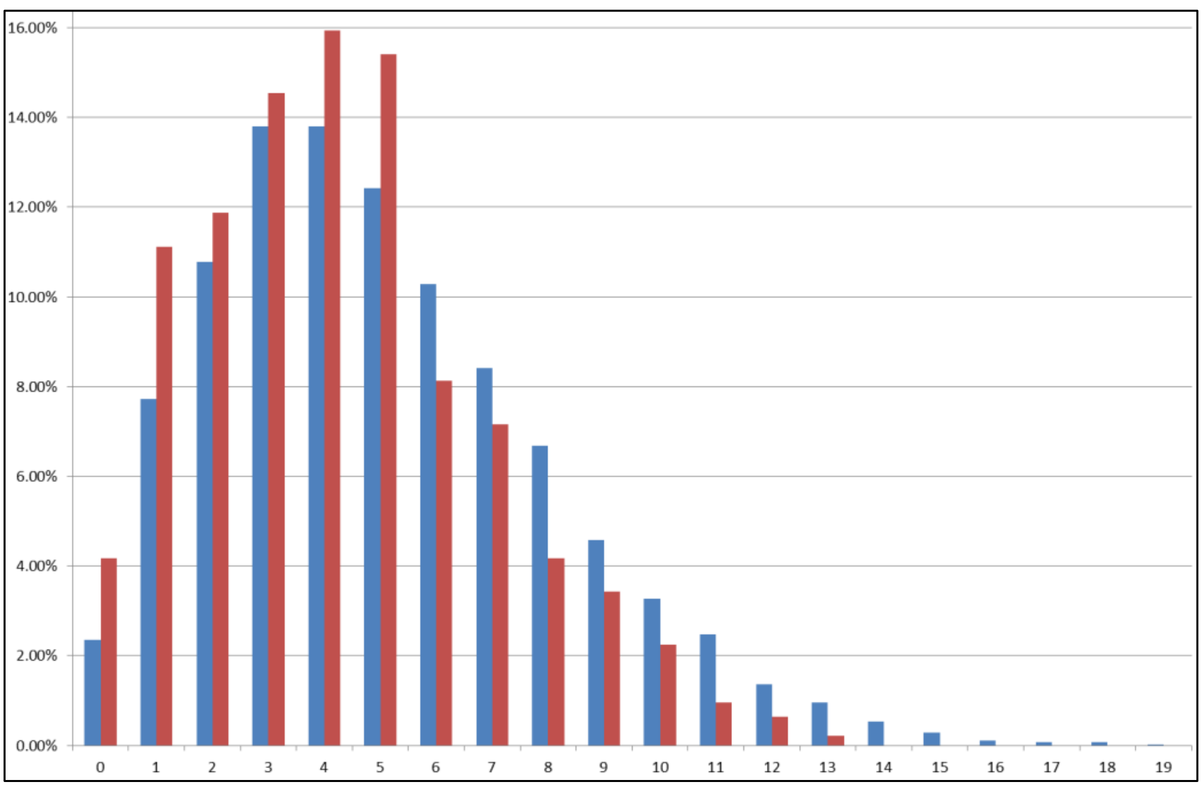


**Figure 21.** Percent of hours with average background wind speeds (blue) and average wind speeds associated with bat passes (red) across the regional network of detectors. Wind speed categories are meters per second. Of the 467,512 hours that detectors have been deployed, wind speed data was available from nearby weather stations for 455,361 hours (97%). Note that some detectors were up to 43 kilometers from the weather station where wind speeds were recorded (X = 16.9 km, SD = 10.5 km).

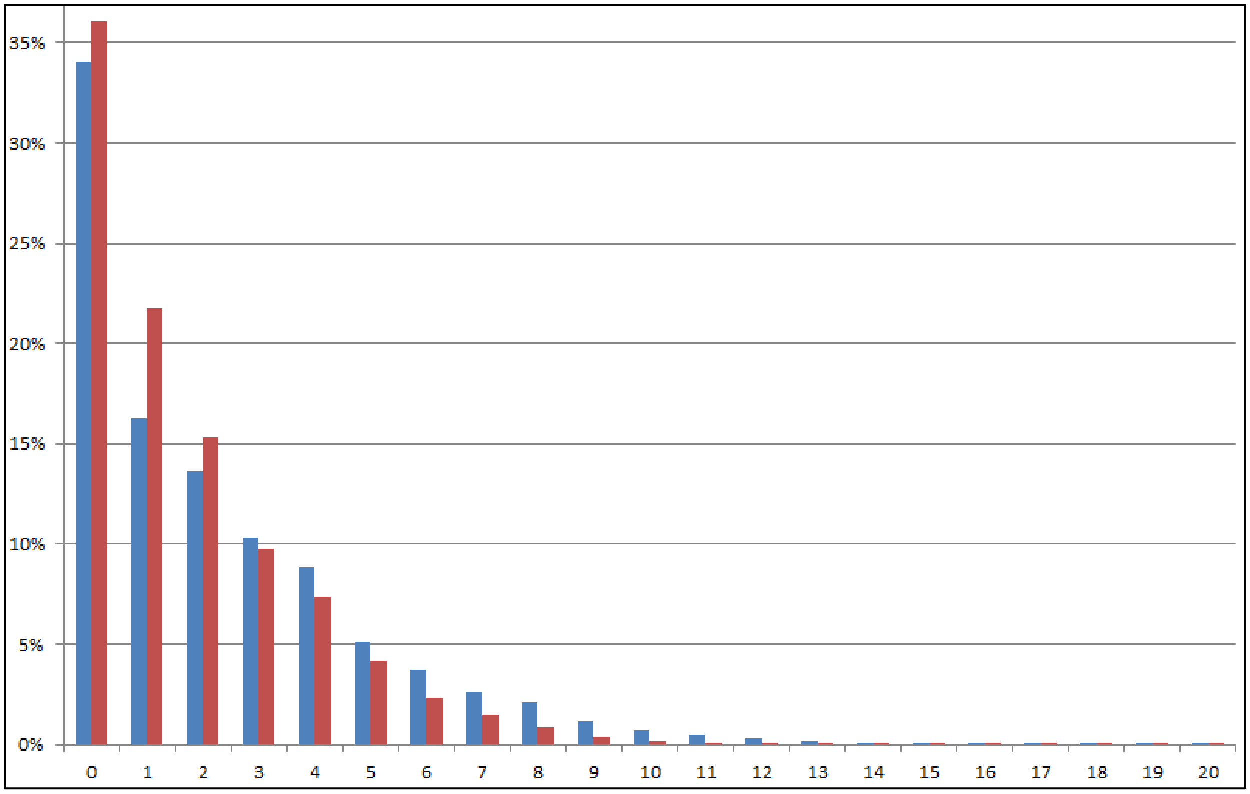
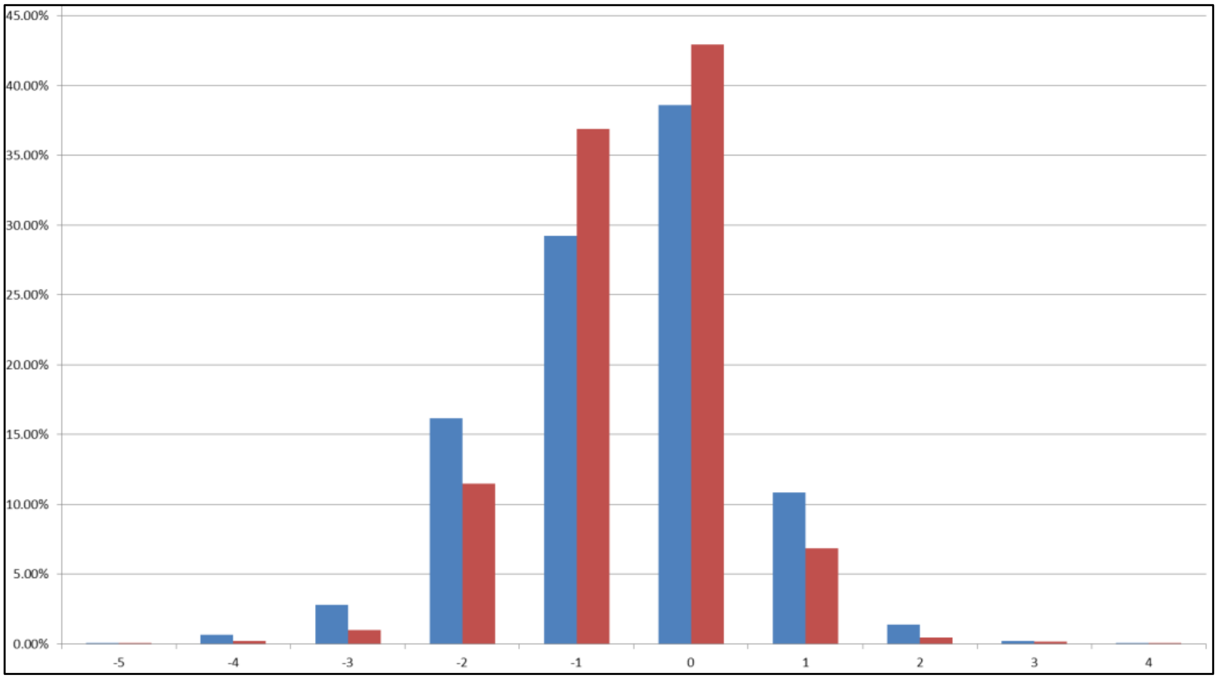


**Figure 22.** Percent of hours with background barometric pressure changes (blue) and barometric pressure changes associated with bat passes (red) for the water treatment ponds (a) and wind turbine (b) at the Malta weather station. Numbers shown are the lower ends of categories of millibars of change per hour.

(a)




(b)

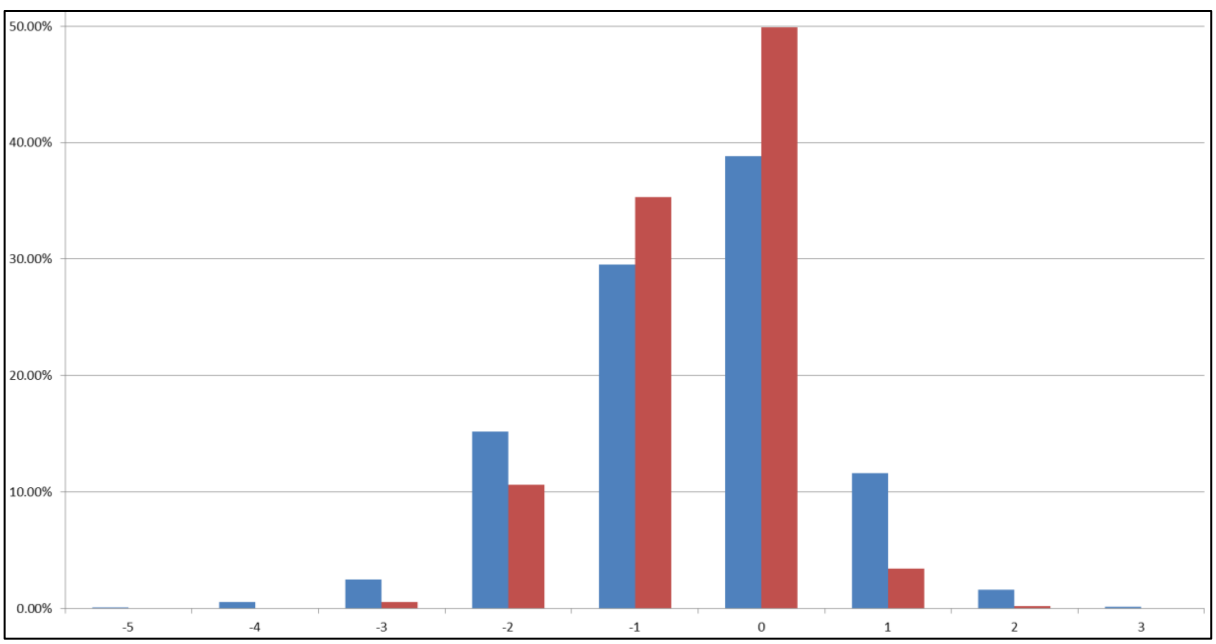


**Figure 23.** Percent of hours with background barometric pressure changes (blue) and barometric pressure changes associated with bat passes (red) across the regional network of detectors. Numbers shown are the lower ends of categories of millibars of change per hour. Of the 467,512 hours that detectors have been deployed, barometric pressure data was available from nearby weather stations for 420,412 hours (90%). Note that some detectors were up to 94 kilometers from the weather station where barometric pressures were recorded (X = 35.4 km, SD = 21.5 km).

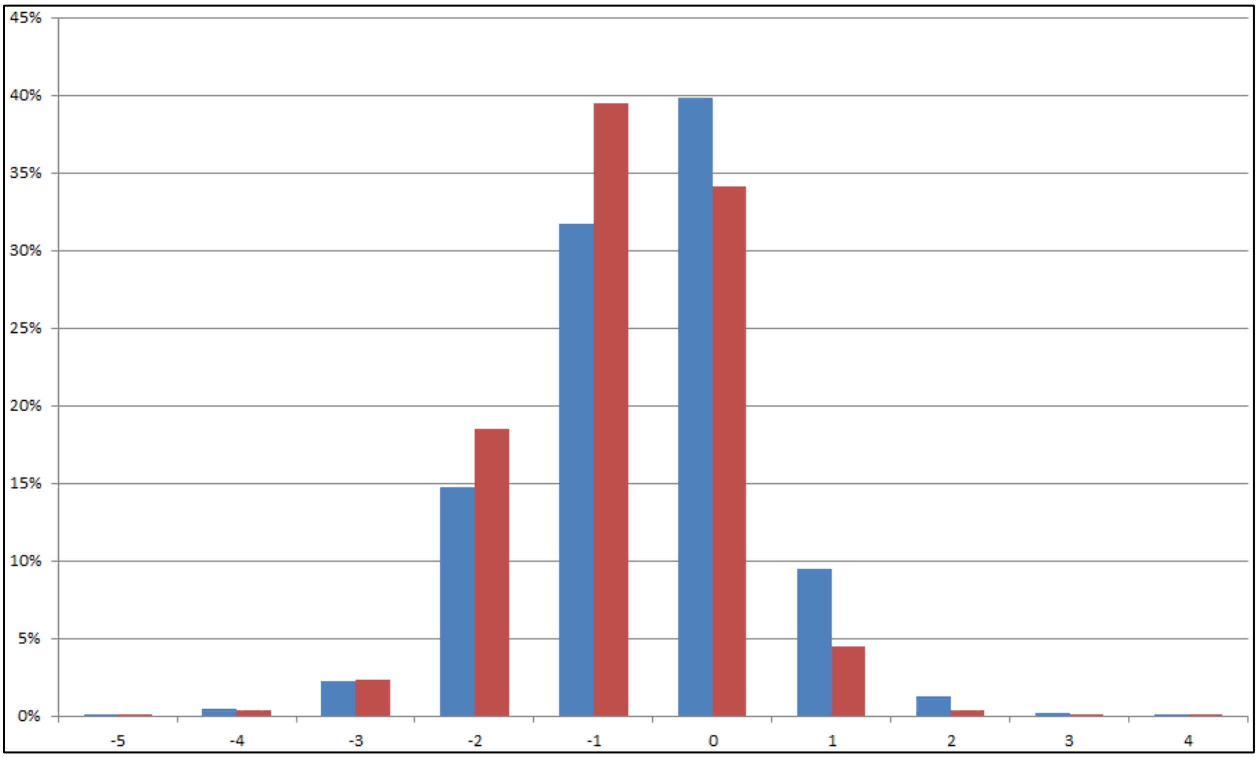
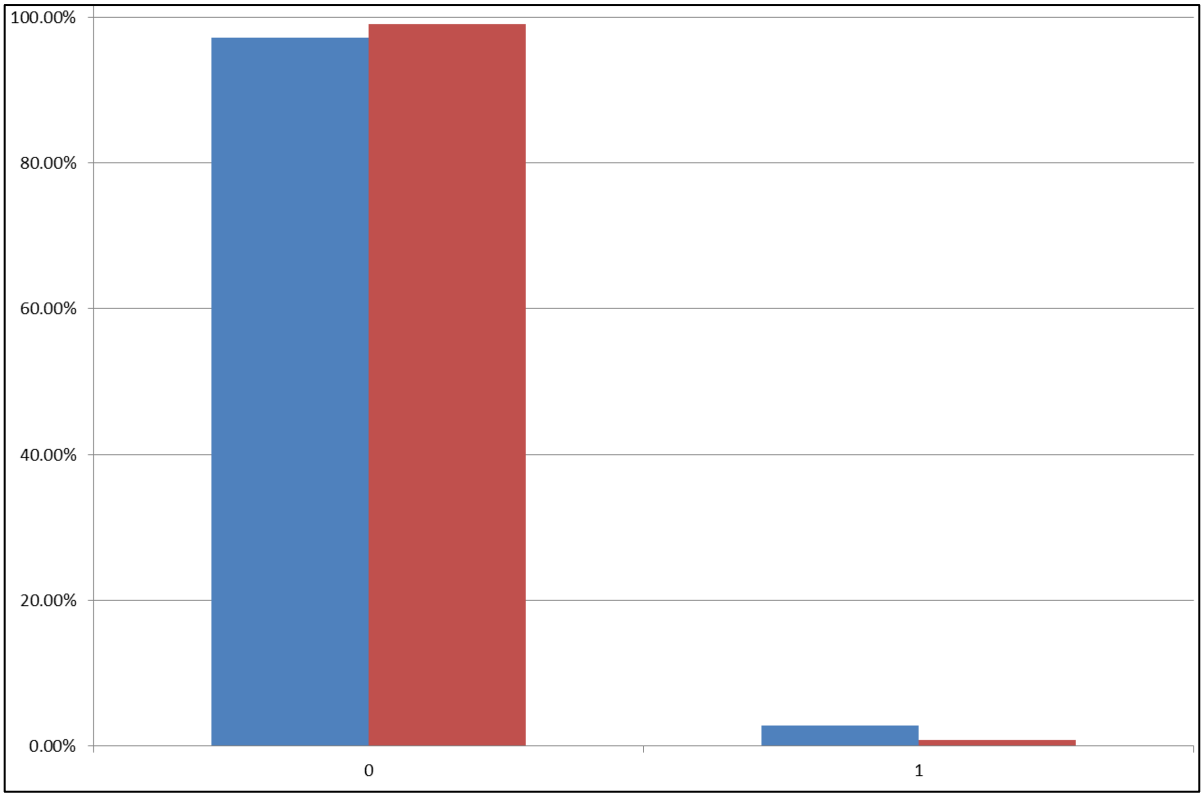


**Figure 24.** Percent of background hours (blue) and hours with bat passes (red) with (0) and without (1) precipitation for the water treatment ponds (a) and wind turbine (b) at the Zortman weather station

(a)




(b)

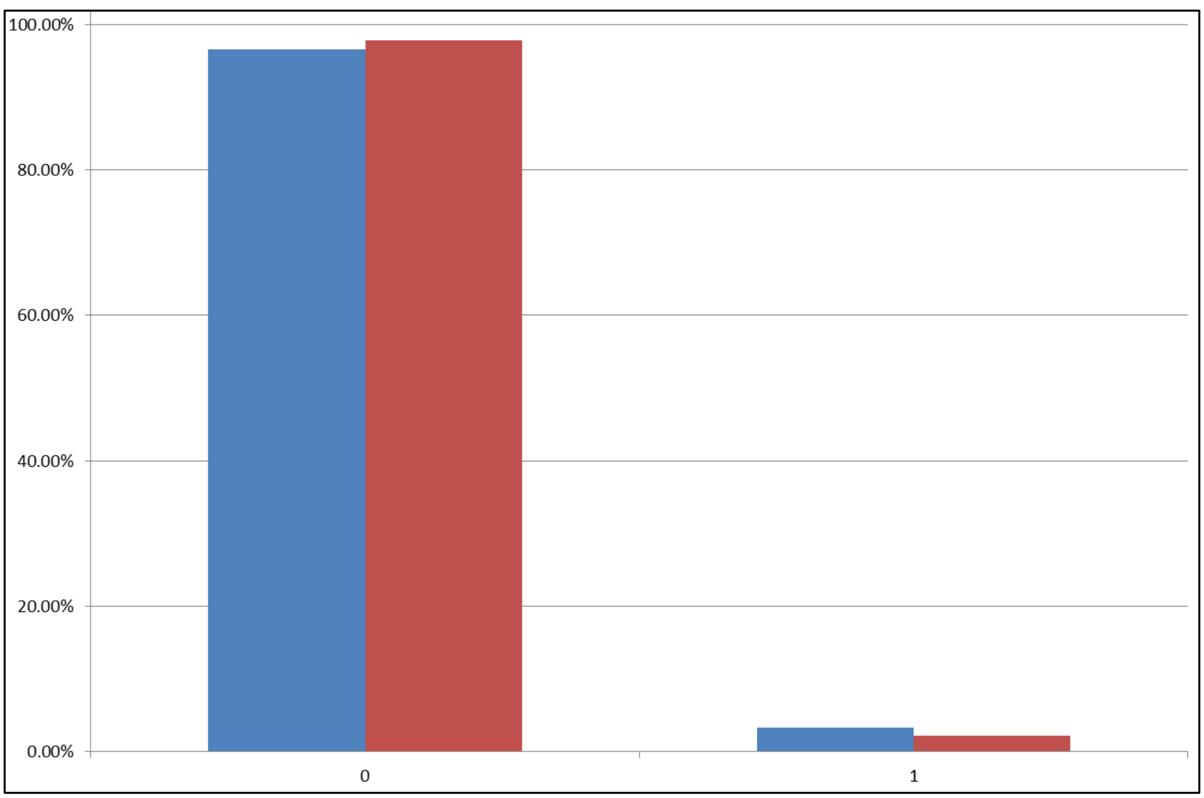


**Figure 25.** Percent of background hours (blue) and hours with bat passes (red) with (0) and without (1) precipitation across the regional network of detectors. Of the 467,512 hours that detectors have been deployed, precipitation data was available from nearby weather stations for 454,006 hours (97%). Note that some detectors were up to 75 kilometers from the weather station where precipitation events were recorded (X = 30.0 km, SD = 14.2 km) and bats are capable of flight within minutes of the passing of a rain shower.

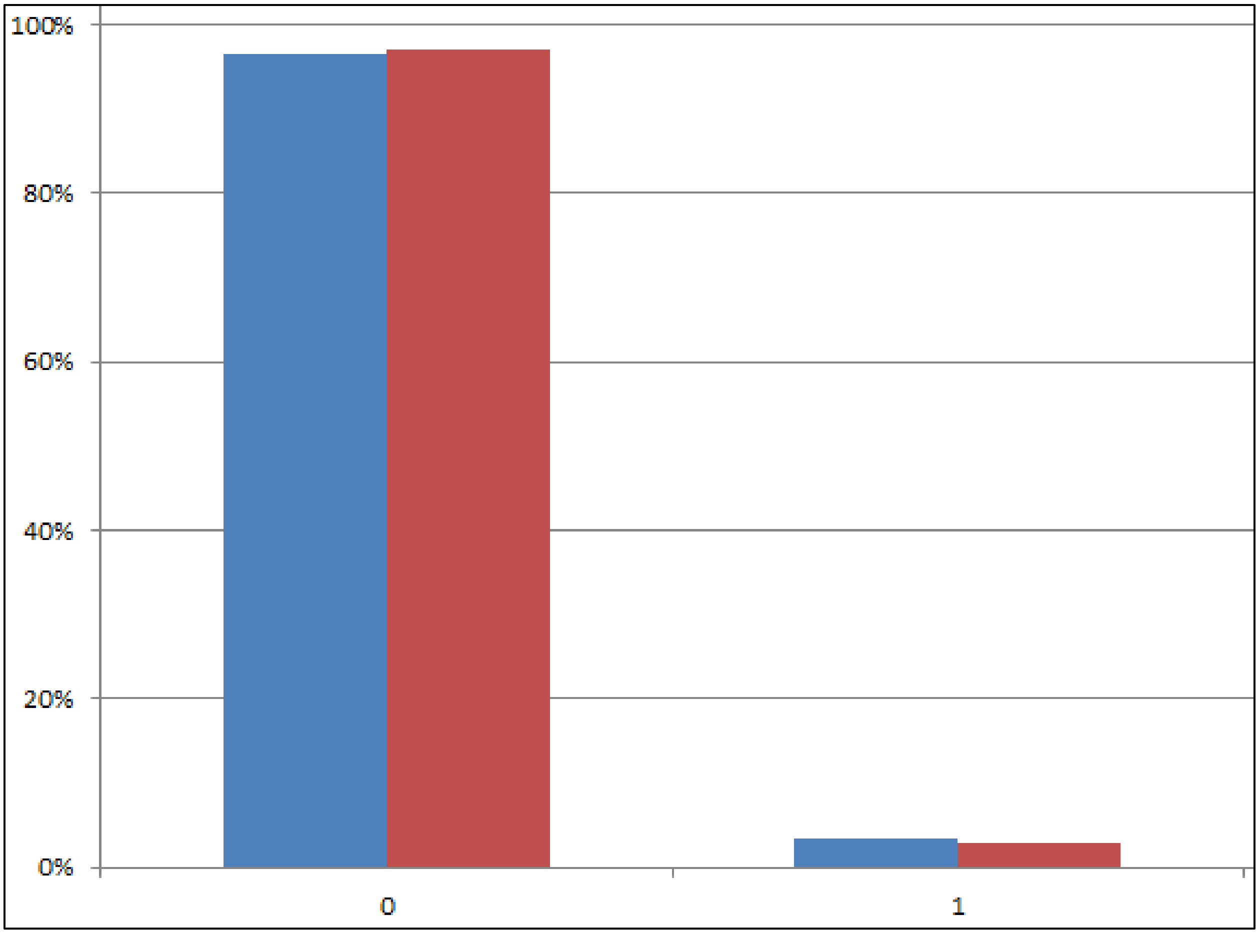
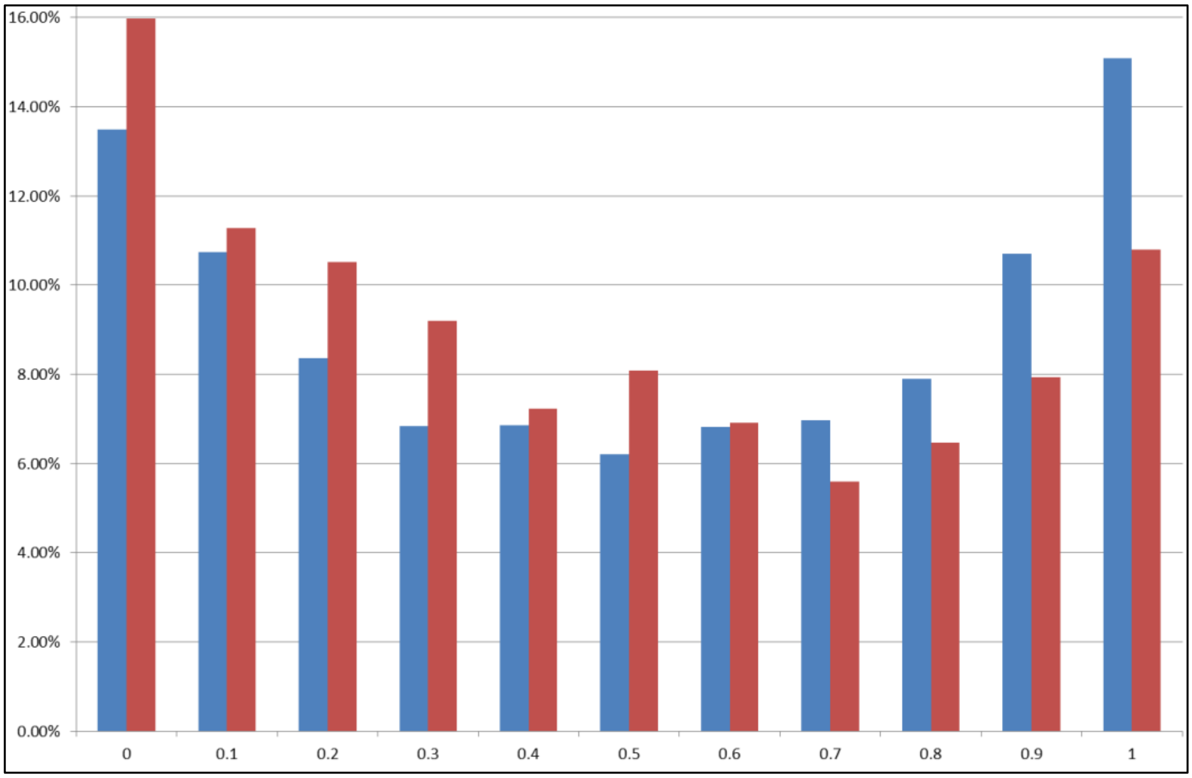


**Figure 26.** Percent of background hours (blue) and hours with bat passes (red) at various moon illumination categories (0 = no illumination and 1 = full moon) whether the moon is above or below the horizon for the water treatment ponds (a) and wind turbine (b)

(a)




(b)

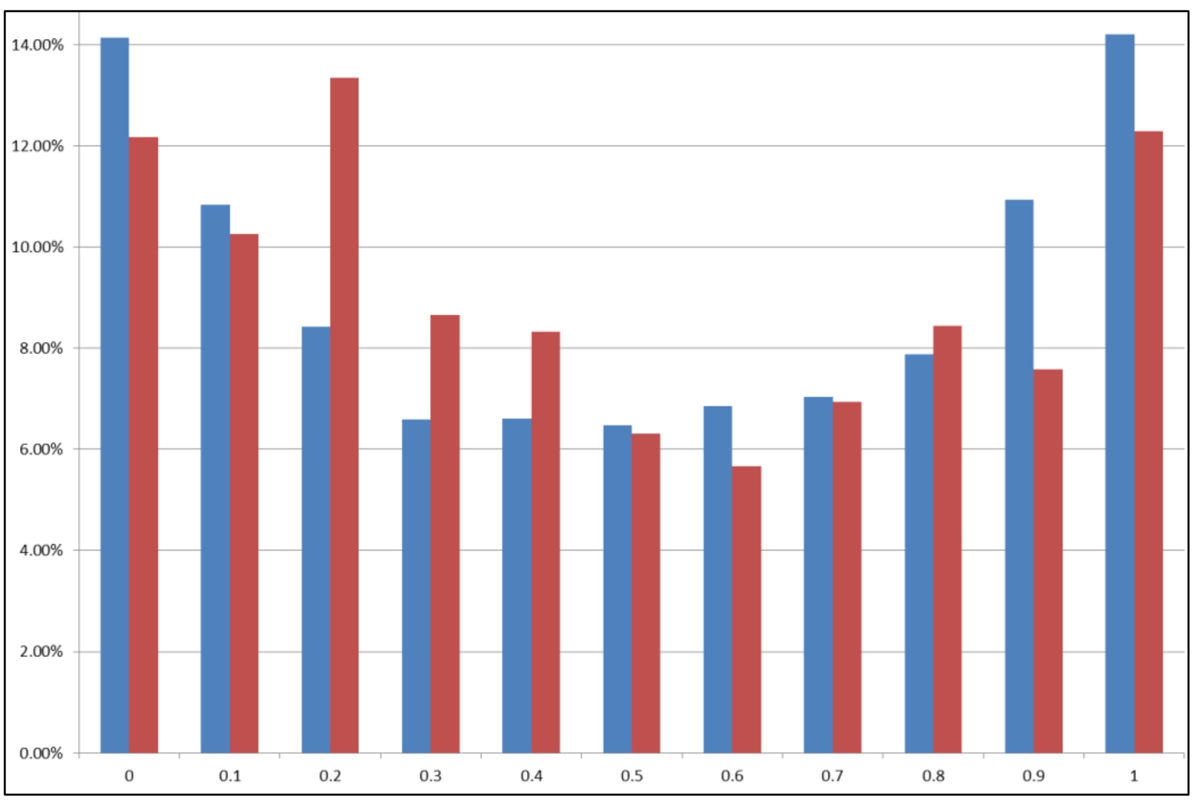


**Figure 27.** Percent of background hours (blue) and hours with bat passes (red) associated with various moon illumination categories (0 = no illumination and 1 = full moon) and with the moon below or above the horizon across the regional network of detectors. Moon illumination values were able to be calculated for 100% of the 467,512 hours that detectors have been deployed.

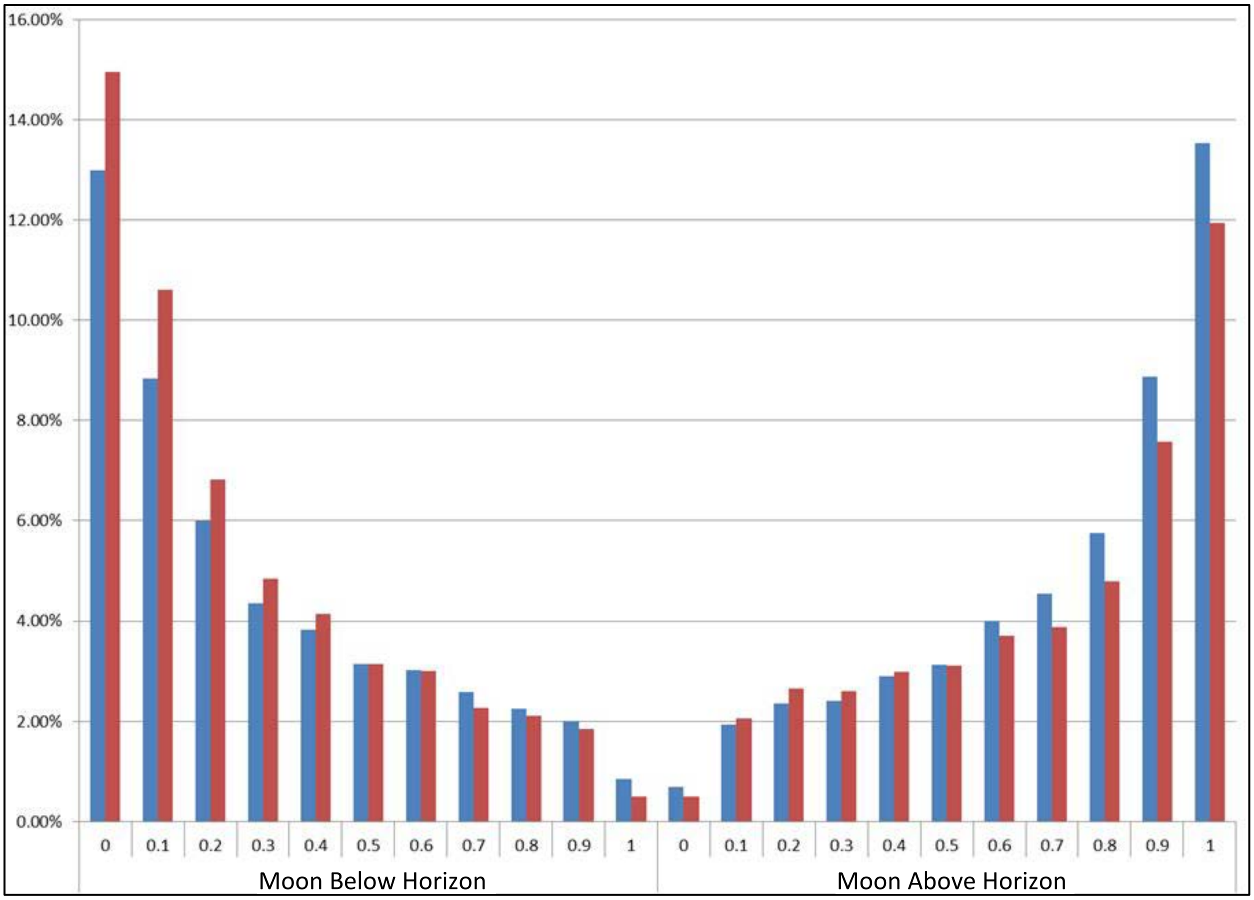
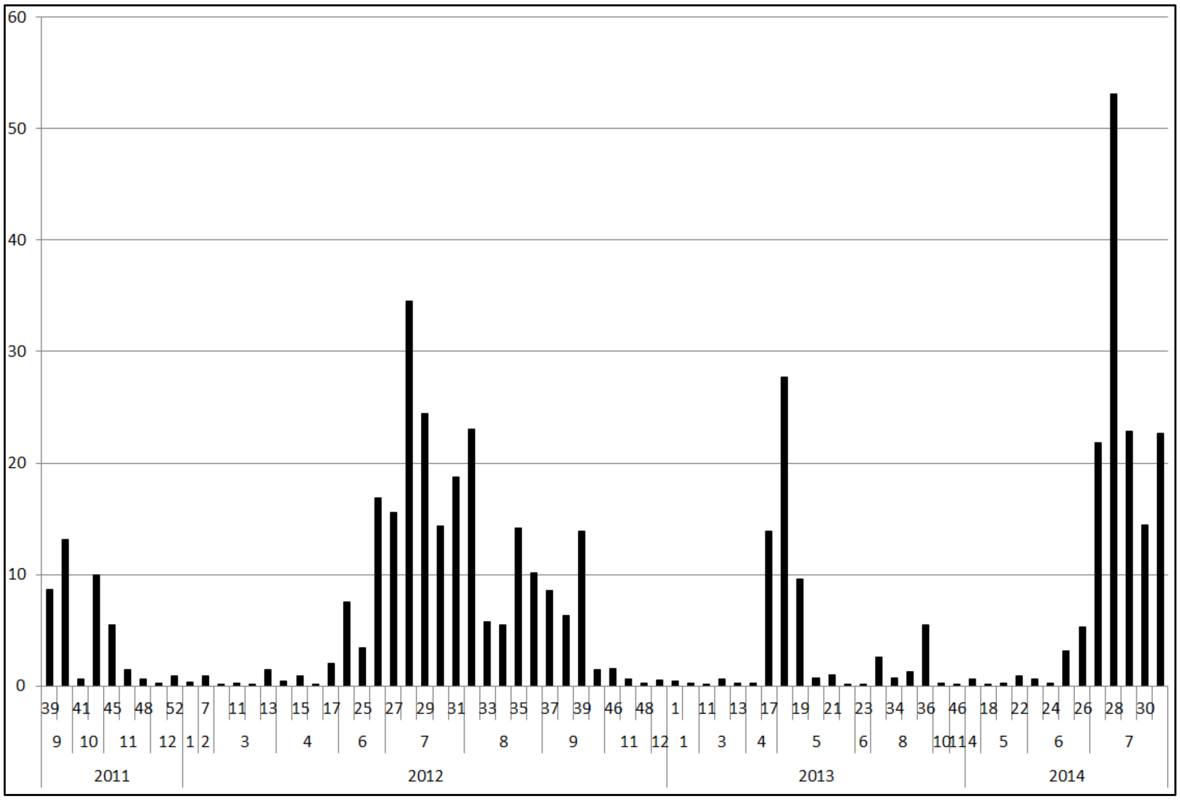


**Figure 28.** Average number of nightly bat passes each week auto-identified as Big Brown Bat at the water treatment ponds (a) and wind turbine (b). Numbers on X axis are years, months, and weeks.

(a)




(b)

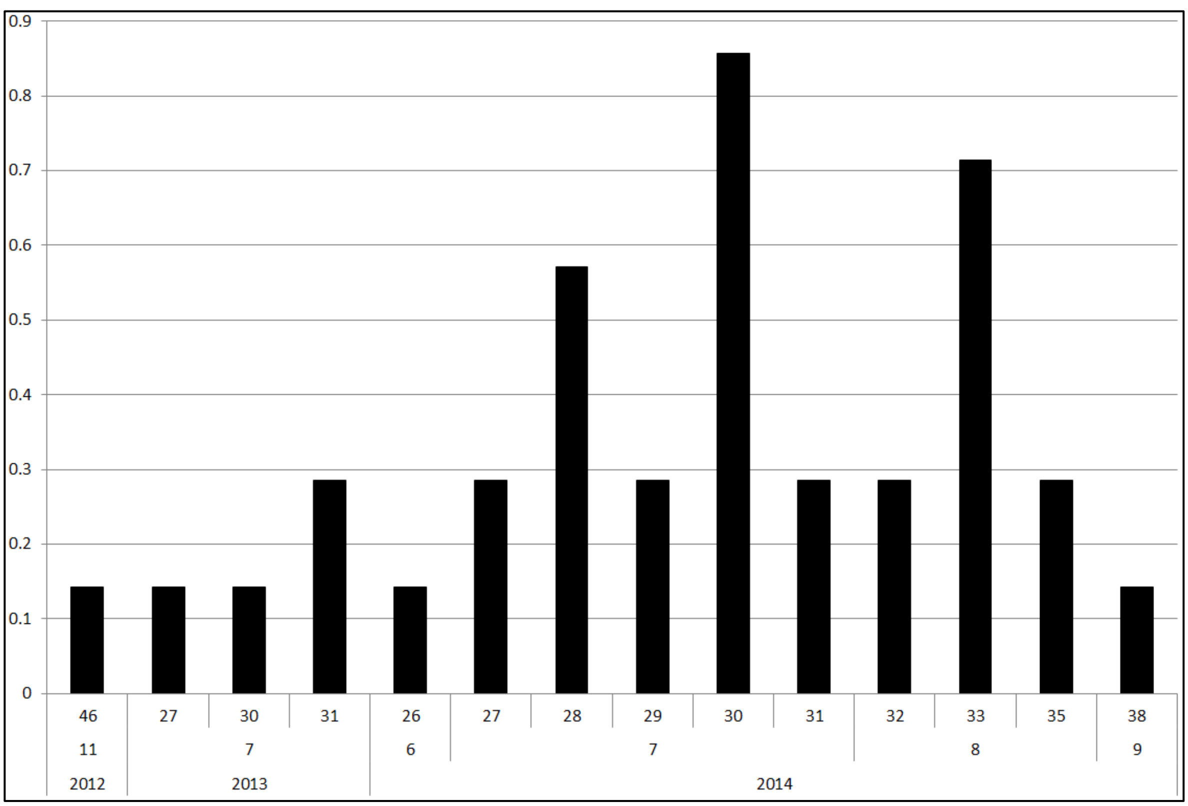
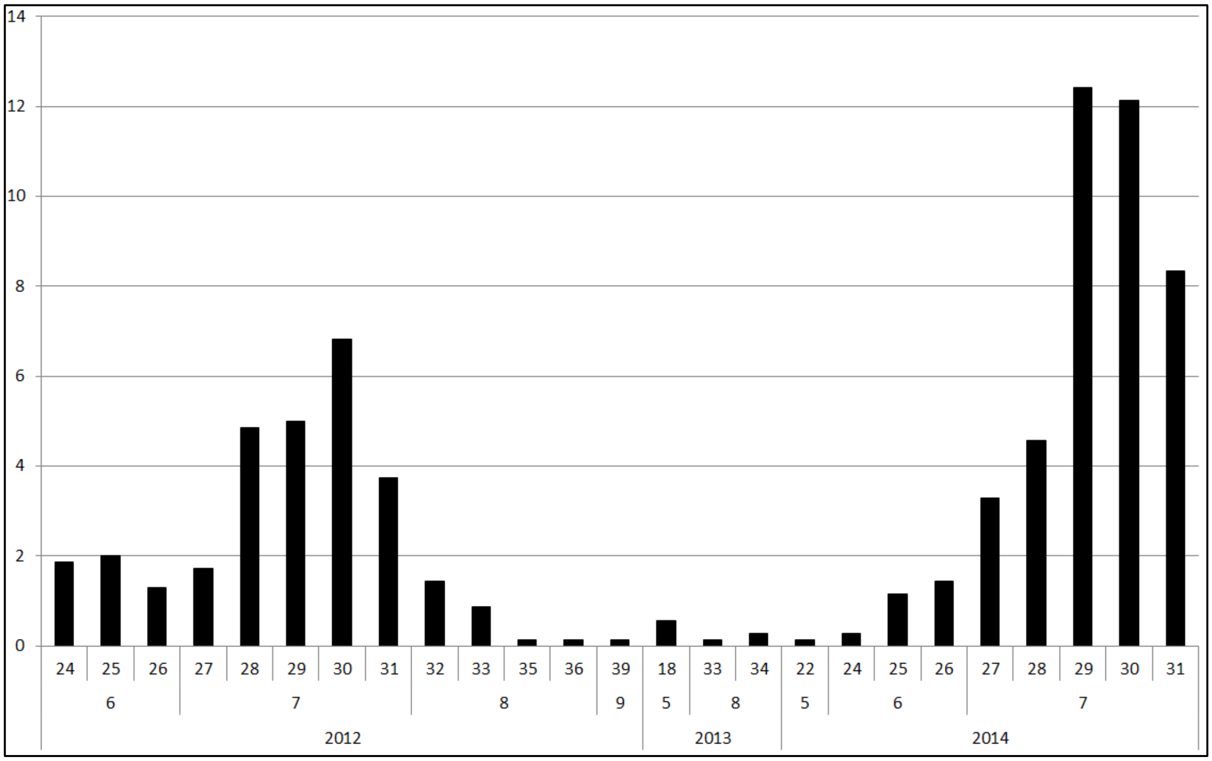


**Figure 29.** Average number of nightly bat passes each week auto-identified as Hoary Bat at the water treatment ponds (a) and wind turbine (b). Numbers on X axis are years, months, and weeks.

(a)




(b)

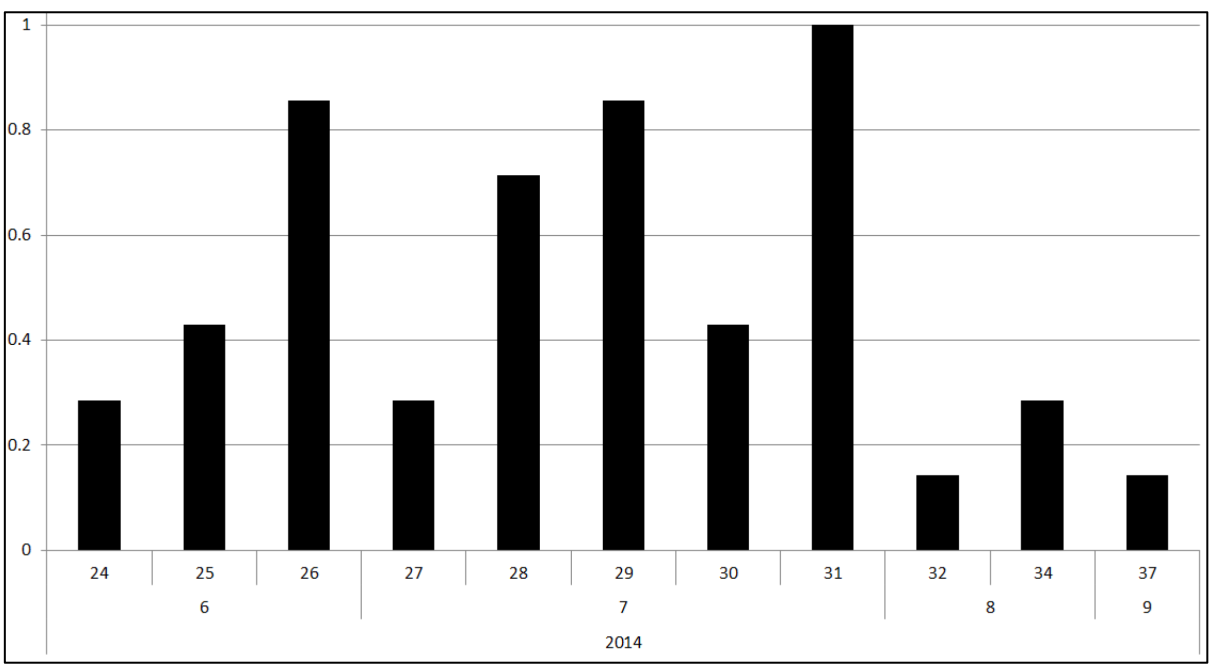
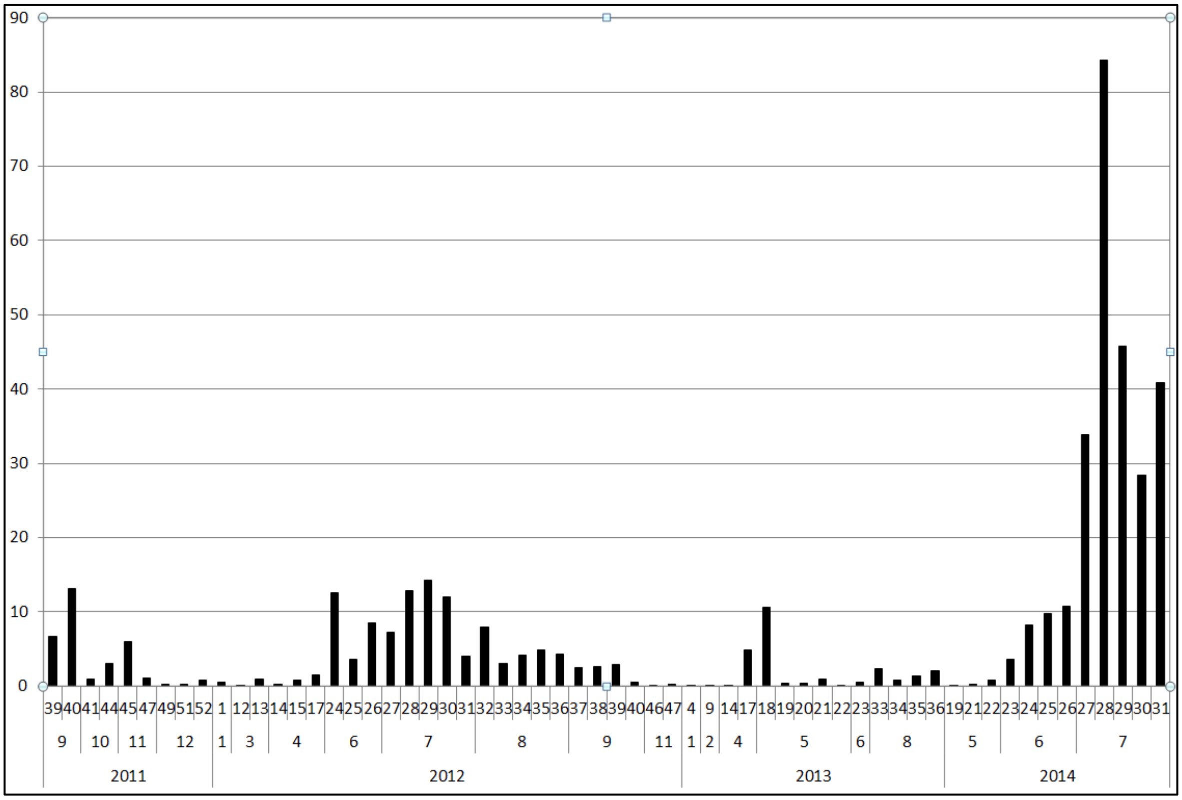


**Figure 30.** Average number of nightly bat passes each week auto-identified as Silver-haired Bat at the water treatment ponds (a) and wind turbine (b). Numbers on X axis are years, months, and weeks.

(a)




(b)

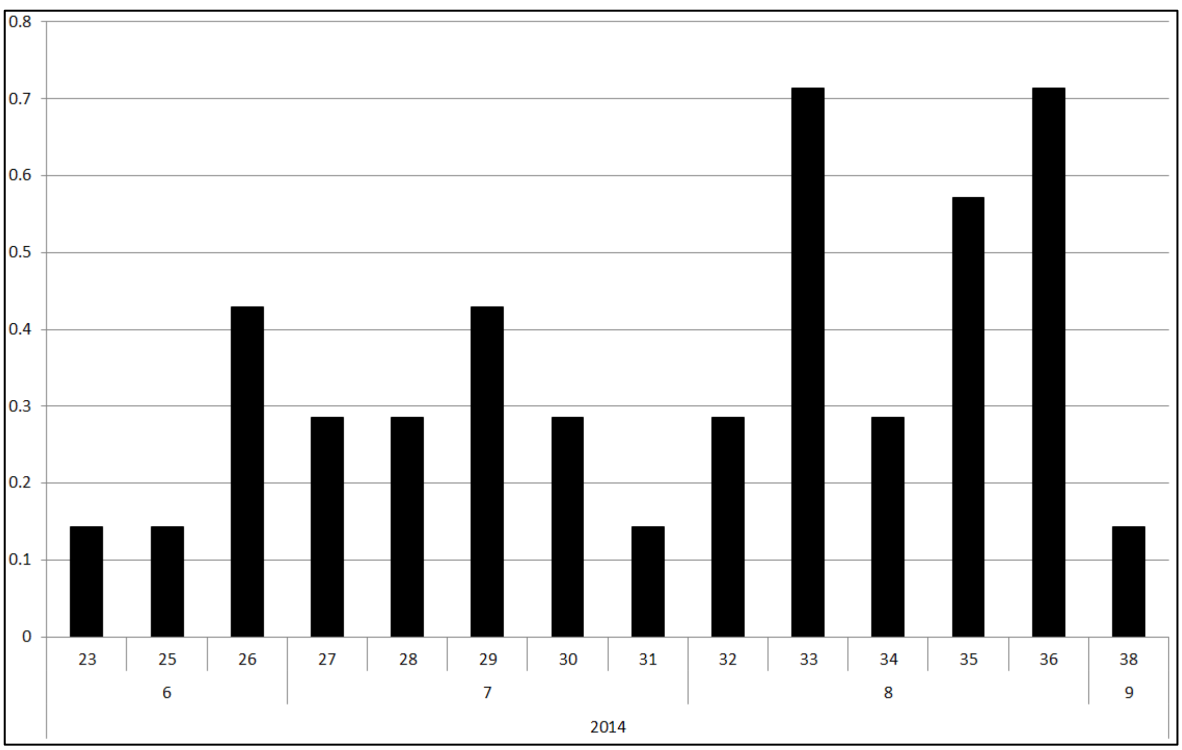
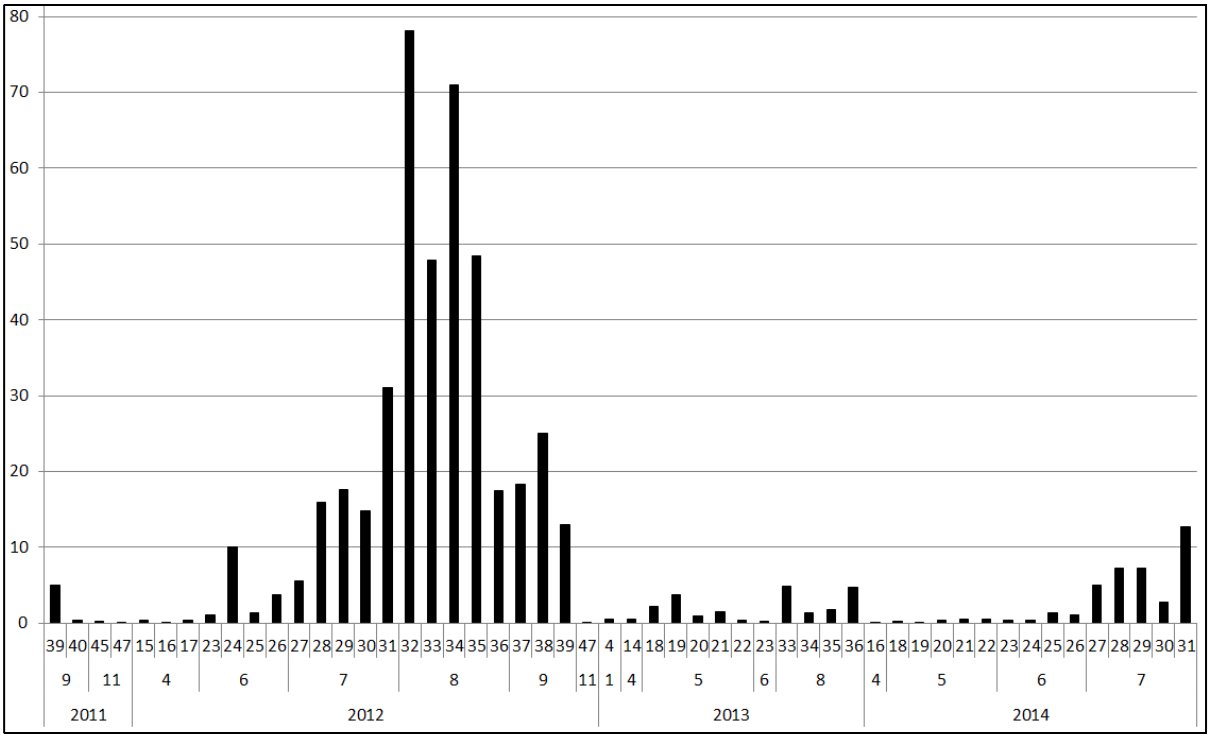


**Figure 31.** Average number of nightly bat passes each week auto-identified as Western Small-footed Myotis at the water treatment ponds (a) and wind turbine (b). Numbers on X axis are years, months, and weeks.

(a)




(b)

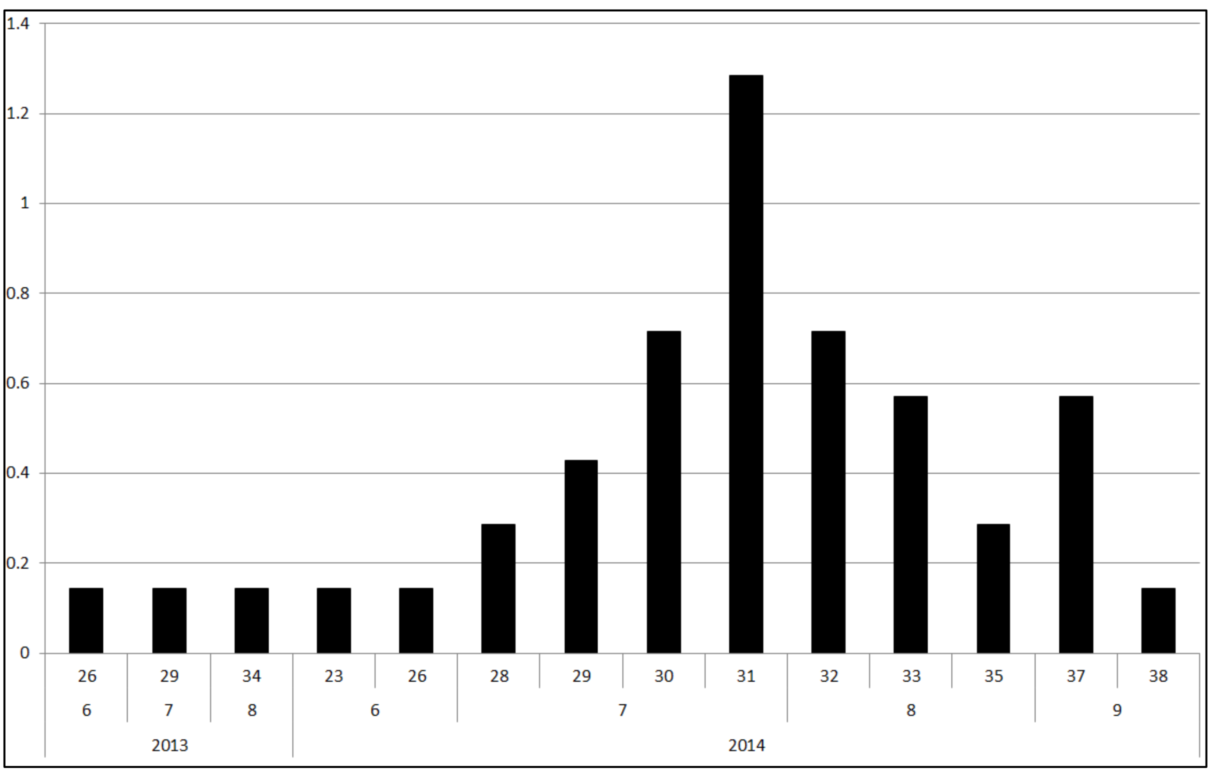
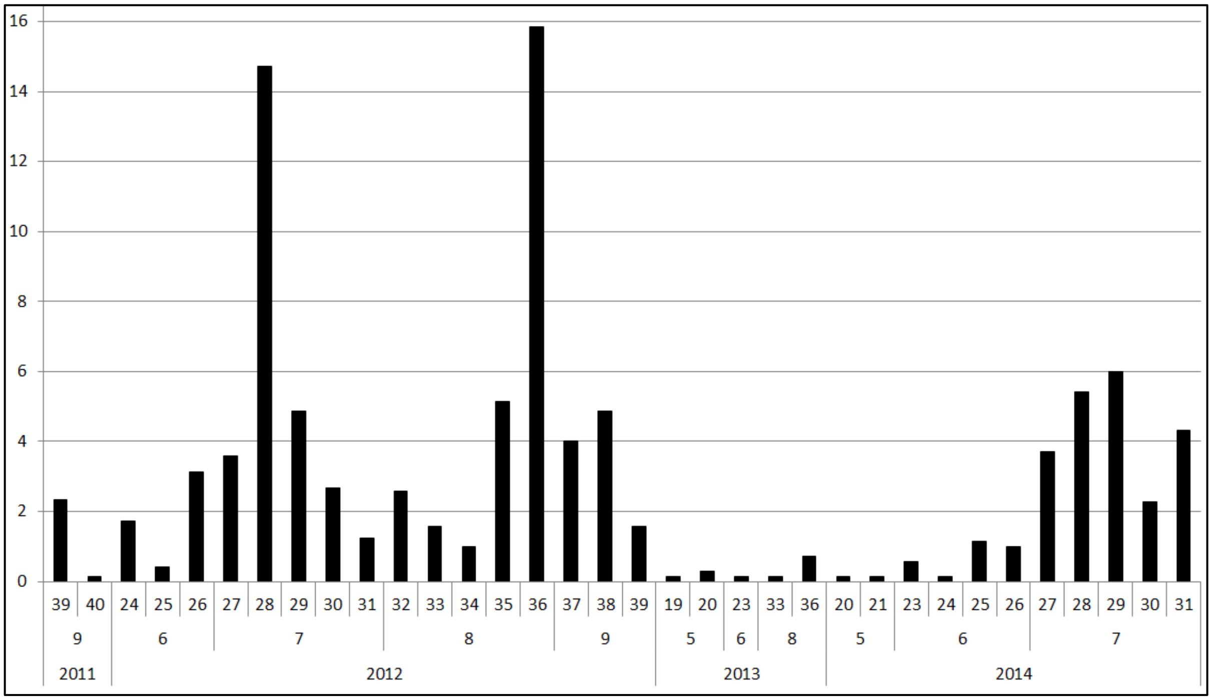


**Figure 32.** Average number of nightly bat passes each week auto-identified as Long-eared Myotis at the water treatment ponds (a) and wind turbine (b). Numbers on X axis are years, months, and weeks.

(a)




(b)

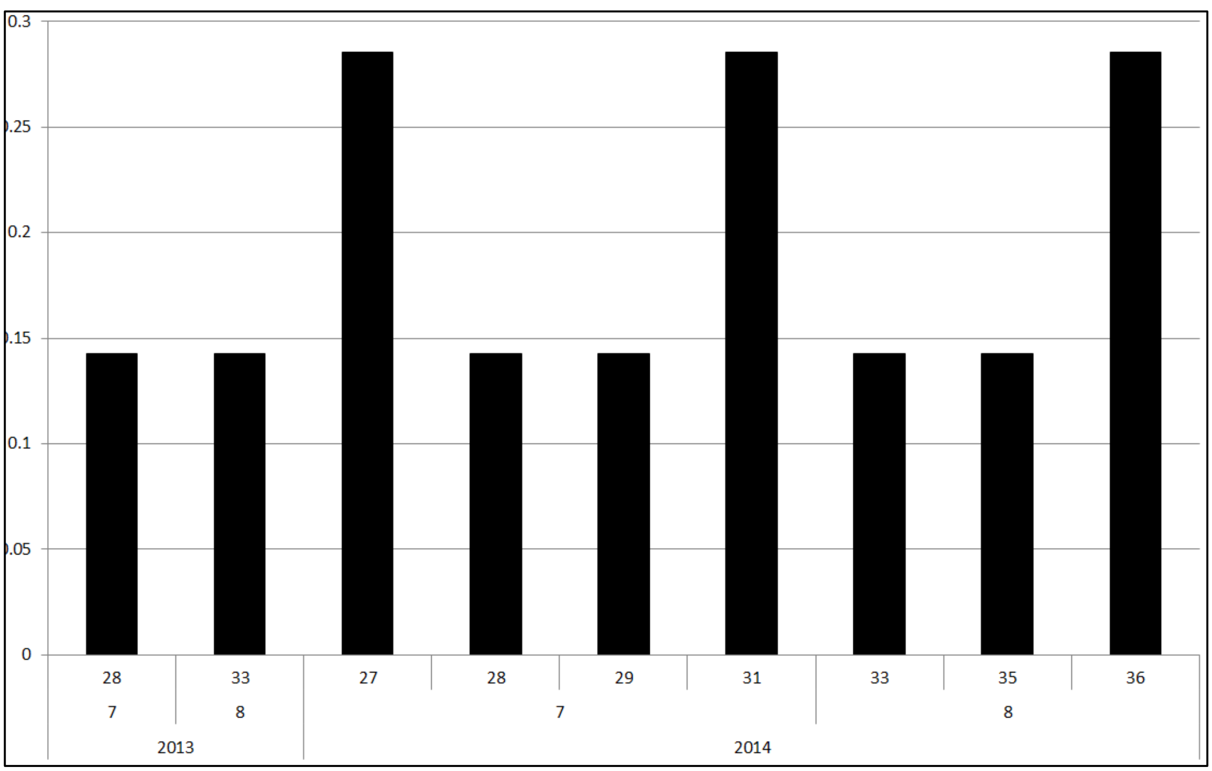
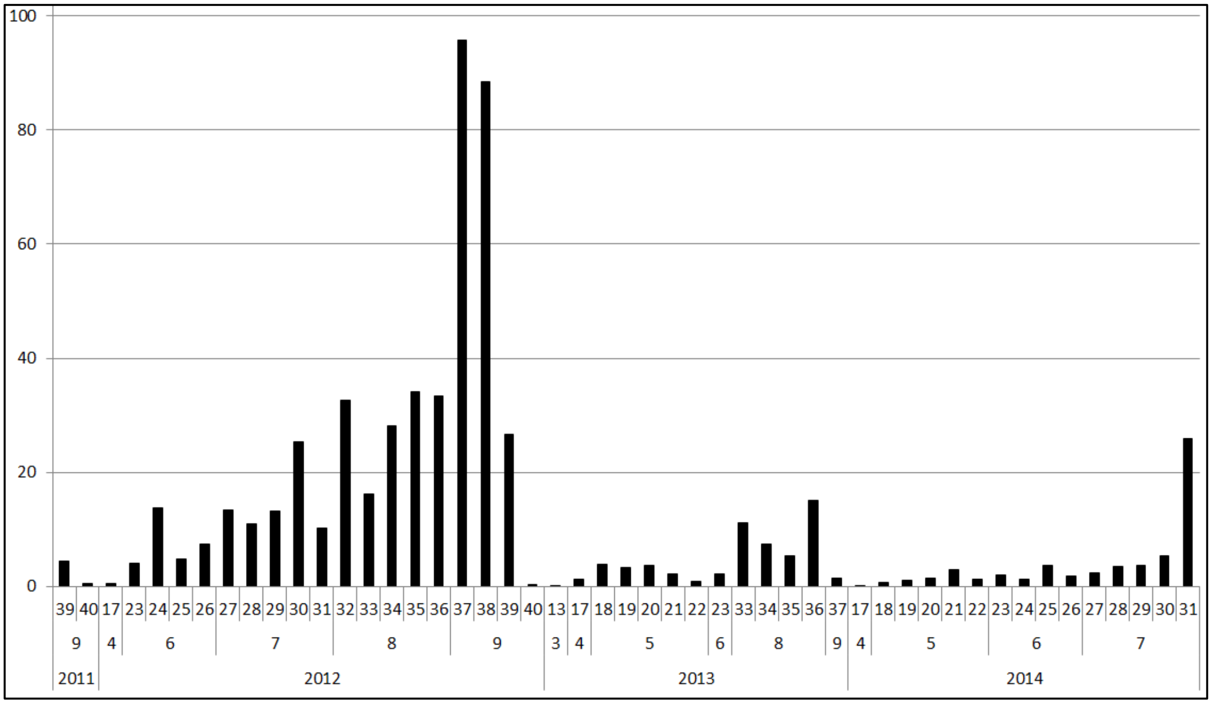
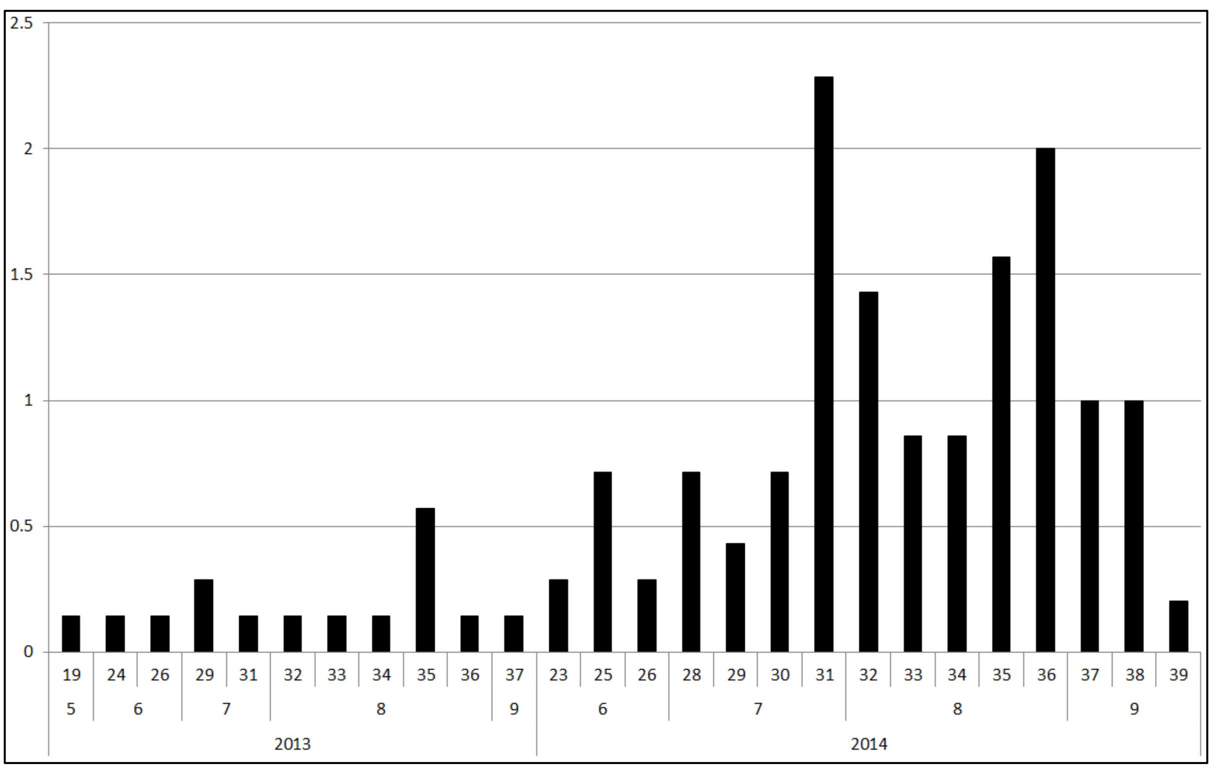


**Figure 33.** Average number of nightly bat passes each week auto-identified as Little Brown Myotis at the water treatment ponds (a) and wind turbine (b). Numbers on X axis are years, months, and weeks.

(a)




(b)



## Appendix A

## References on Wind Turbine and other Human Structure Impacts on Bats

Compiled by Bryce A. Maxell, Senior Zoologist, Montana Natural Heritage Program

September 2015

An * in front of a citation, indicates the article has particular value for wind turbine impacts to bats and turbine management in Montana. Additional information on wind turbine impacts to bats and other wildlife can be found at the Wind-Wildlife Impacts Literature Database (WILD) at http://wild.nrel.gov


Ahlén, I. 2003. Wind turbines and bats—a pilot study. Uppsala, Sweden. http://publikationer.slu.se/Filer/08WindBatFinalReport.pdf

Anderson, R.L., D. Strickland, J. Tom, N. Neumann, W. Erickson, J. Cleckler, G. Mayorga, G. Nuhn, A. Leuders, J. Schneider, L. Backus, P. Becker and N. Flagg. 2000. Avian monitoring and risk assessment at Tehachapi Pass and San Gorgonio Pass wind resource areas, California: Phase 1 preliminary results. Proceedings of the National Avian-Wind Power Planning Meeting 3:31-46. National Wind Coordinating Committee, Washington, D.C.

Arnett, E. B. (Tech. ed.). 2005. Relationships between bats and wind turbines in Pennsylvania and West Virginia: An assessment of bat fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines. A final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International.

*Arnett, E.B. 2006. A preliminary evaluation on the use of dogs to recover bat fatalities at wind energy facilities. Wildlife Society Bulletin 34(5):1440-1445.

*Arnett, E.B., W.K. Brown, W.P. Erickson, J.K. Fiedler, B.L. Hamilton, T.H. Henry, A. Jain, G.D. Johnson, J. Kerns, R.R. Koford, C.P. Nicholson, T.J. O'Connell, M.D. Piorkowski, and R.D. Tankersley, Jr. 2008. Patterns of bat fatalities at wind energy facilities in North America. Journal of Wildlife Management 72(1):61-78.

Arnett E.B., J.P. Hayes, M.M.P. Huso. 2006. An evaluation of the use of acoustic monitoring to predict bat fatality at a proposed wind facility in southcentral Pennsylvania. An annual report submitted to the bats and wind energy cooperative. Austin, Texas, USA. http://www.batsandwind.org/pdf/precon_pa.pdf

*Arnett E.B., C. Hein, M. Schirmacher, M.M.P. Huso, and J. Szewczak. 2013. Evaluating the effectiveness of an ultrasonic acoustic deterrent for reducing bat fatalities at wind turbines. PLoS ONE 8(6):e65794. doi:10.1371/journal.pone.0065794

Arnett, E.B., M.M.P. Huso, D.S. Reynolds, and M. Schirmacher. 2007. Patterns of pre-construction bat activity at a proposed wind facility in northwest Massachusetts. Annual report prepared for the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA. 35 p.

*Arnett, E.B., M.M.P. Huso, M.R. Schirmacher, and J.P. Hayes. 2011. Altering turbine speed reduces bat mortality at wind-energy facilities. Frontiers in Ecology and the Environment 9(4):209-214.

Avery, M. and T. Clement. 1972. Bird mortality at four towers in eastern North Dakota: Fall 1972. Prairie Naturalist 4:87-95.

*Baerwald, E.F. and R.M.R. Barclay. 2009. Geographic variation in activity and fatality of migratory bats at wind energy facilities. Journal of Mammalogy 90(6):1341-1349.

*Baerwald, E.F. and R.M.R. Barclay. 2011. Patterns of activity and fatality of migratory bats at a wind energy facility in Alberta, Canada. Journal of Wildlife Management 75(5):1103-1114.

Baerwald, E.F., G.H. D'Amours, B.J. Klug, and R.M.R. Barclay. 2008. Barotrauma is a significant cause of bat fatalities at wind turbines. Current Biology 18(16):R695-R696.

*Baerwald, E.F., J. Edworthy, M. Holder, and R.M.R. Barclay. 2009. A large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. Journal of Wildlife Management 73(7):1077-1081.

*Barclay, R.M.R., E.F. Baerwald, and J.C. Gruver. 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Canadian Journal of Zoology 85:381-387.

Bennett, V.J. and A.M. Hale. 2014. Red aviation lights on wind turbines do not increase bat-turbine collisions. Animal Conservation 17:354-358.

Bernardino, J., R. Bispo, H. Costa, and M. Mascarenhas. 2013. Estimating bird and bat fatality at wind farms: a practical overview of estimators, their assumptions and limitations. New Zealand Journal of Zoology 40(1):63-74.

Chang, T. E. Nielson, W. Auberle, F.I. Solop. 2013. A quantitative method to analyze the quality of EIA information in wind energy development and avian/bat assessments. Environmental Impact Assessment Review 38:142-150.

Crawford, R.L. and W.W. Baker. 1981. Bats killed at a north Florida television tower: a 25-year record. Journal of Mammalogy 62:651-652.

*Cryan, P.M. 2008. Mating behavior as a possible cause of bat fatalities at wind turbines. Journal of Wildlife Management 72(3): 845-849.

Cryan, P.M. and R.M.R. Barclay. 2009. Causes of bat fatalities at wind turbines: hypotheses and predictions. Journal of Mammalogy 90(6):1330-1340.

Cryan, P.M. and A.C. Brown. 2007. Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines. Biological Conservation 139:1-11.

*Cryan, P.M., P.M. Gorresen, C.D. Hein, M.R. Schirmacher, R.H. Diehl, M.M. Huso, D.T.S. Hayman, P.D. Fricker, F.J. Bonaccorso, D.H. Johnson, K. Heist, and D.C. Dalton. 2014. Behavior of bats at wind turbines. Proceedings of the National Academy of Sciences 111(42):15126-15131.

Cryan, P.M., J.W. Jameson, E.F. Baerwald, C.K.R. Willis, R.M.R. Barclay, E.A. Snider, and E.G. Chrichton. 2012. Evidence of late-summer mating readiness and early sexual maturation in migratory tree-roosting bats found dead at wind turbines. PLoS One 7(10):e47586. Doi:10.1371/journal.pone.0047586

Cryan, P.M., C.A. Stricker, and M.B. Wunder. 2014. Continental-scale, seasonal movements of a heterothermic migratory tree bat. Ecological Applications 24(4):602-616.

Cullinan, V.I., S. Matzner, and C.A. Duberstein. 2015. Classification of birds and bats using flight tracks. Ecological Informatics 27:55-63.

DeBlase, A.F. and J.B. Cope. 1967. An Indiana bat impaled on barbed wire. American Midland Naturalist 77:238.

Dedon, M., S. Byrne, J. Aycrigg, and P. Hartman. 1989. Bird mortality in relation to the Mare Island 115-kV transmission line: progress report 1988/1989. Department of the Navy, Western Division, Naval Facilities Engineering Command, Office of Environmental Management, San Bruno, California. Report 443-89.3. 150pp.

Denys, G.A. 1972. Hoary bat impaled on barbed wire. Jack-Pine Warbler 50:63.

Diehl, R.H. 2013. The airspace is habitat. Trends in Ecology and Evolution 28(7):377-379. doi.org/10.1016/j.tree.2013.02.015

Doty, A.C. and A.P. Martin. 2013. Assessment of bat and avian mortality at a pilot wind turbine at Coega, Port Elizabeth, Eastern Cape, South Africa. New Zealand Journal of Zoology 40(1):75-80.

*Drake, D., C.S. Jennelle, J.N. Liu, S.M. Grodsky, S. Schumacher, and M. Sponsler. 2015. Regional analysis of wind turbine-caused bat mortality. Acta Chiropterologica 17(1)179-188.

Erickson, W.P., B. Gritski, and K. Kronner, 2003. Nine Canyon Wind Power Project Avian and Bat Monitoring Annual Report. Technical report submitted to Energy Northwest and the Nine Canyon Technical Advisory Committee.

Erickson, W.P., J. Jeffrey, K. Kronner, and K. Bay. 2003. Stateline Wind Project Wildlife Monitoring Annual Report, Results for the Period July 2001 – December 2002. Technical report submitted to FPL Energy, the Oregon Office of Energy, and the Stateline Technical Advisory Committee.

Erickson, W.P., G.D. Johnson, M.D. Strickland, and K. Kronner. 2000. Avian and bat mortality associated with the Vansycle Wind Project, Umatilla County, Oregon: 1999 study year. Technical Report prepared by WEST, Inc. for Umatilla County Department of Resource Services and Development, Pendleton, Oregon. 21p.

Erickson, W., G. Johnson, D. Young, D. Stickland, R. Good, M. Bourassa, K. Bay, K. Sernka. 2002. Synthesis and comparison of baseline avian and bat use, raptor nesting and mortality information from proposed and existing wind developments. Report to Bonneville Power Administration. West Inc., Cheyenne, Wyoming. 124 p.

Ferreira, D., C. Frexio, J.A. Cabral, R. Santos, and M. Santos. 2015. Do habitat characteristics determine mortality risk for bats at wind farms? Modelling susceptible species activity patterns and anticipating possible mortality events. Ecological Informatics 28:7-18.

Fiedler, J.K. 2004. Assessment of bat mortality and activity at Buffalo Mountain Windfarm, eastern Tennessee. M.S. Thesis, University of Tennessee, Knoxville.

Fiedler J.K., T.H. Henry, R.D. Tankersley, and C.P. Nicholson. 2007. Results of bat and bird mortality monitoring at the expanded Buffalo Mountain Windfarm, 2005. Tennessee Valley

Authority. http://www.tva.gov/environment/bmw_report/results.pdf

Ganier, A.F. 1962. Bird casualties at a Nashville TV tower. Migrant 33:58-60.

Gollop, M.A. 1965. Bird migration collision casualties at Saskatoon. Blue Jay 23:15-17.

Grodsky, S.M., M.J. Behr, A. Gendler, D. Drake, B.D. Dieterle, R.J. Rudd, and N.L. Walrath. 2011. Investigating the causes of death for wind turbine-associated bat fatalities. Journal of Mammalogy 92(5):917-925.

*Grodsky, S.M., C.S. Jennelle, D. Drake, T. Virzi. 2012. Bat mortality at a wind-energy facility in southeastern Wisconsin. Wildlife Society Bulletin 36(4):773-783.

Hayes, J.P. and D.L. Waldien. 2000. Potential influences of the proposed Condon Wind Project on bats. Unpublished report prepared for CH2MHILL, Portland, Oregon. 14pp.

Hayes, J.P. and D.L. Waldien. 2000. Potential influences of the Stateline wind project on bats. Unpublished report prepared for CH2MHILL, Portland, Oregon.

*Hayes, M. 2013. Bats killed in large numbers at United States wind energy facilities. BioScience 63(12):975-979.

Higgins, K.F., R.G. Osborn, C.D. Dieter, and R.E. Usgaard. 1996. Monitoring of seasonal bird activity and mortality at the Buffalo Ridge Wind Resource Area, Minnesota, 1994-1995. Completion Report for the Research Period May 1, 1994 - December 31, 1995. Unpubl. report prepared for Kenetech Wind power, Inc. by the South Dakota Cooperative Fish and Wildlife Research Unit, Brookings, SD. 84pp.

*Horn, J.W., E.B. Arnett, and T.H. Kunz. 2008. Behavioral responses of bats to operating wind turbines. Journal of Wildlife Management 72(1):123-132.

Howe, R.W., W. Evans, and A.T. Wolf. 2002. Effects of wind turbines on birds and bats in northeastern Wisconsin. Wisconsin Public Service Corporation, Madison, Wisconsin

Howell, J.A. 1997. Bird mortality at rotor swept area equivalents, Altamont Pass and Montezuma Hills, California. Transactions of the Western Section of the Wildlife Society 33:24-29.

Howell, J.A. and J.E. Didonato. 1991. Assessment of avian use and mortality related to wind turbine operations, Altamont Pass, Alameda and Contra Costa Counties, California, September 1998 through August 1989. Final report submitted to U.S. Wind power, Inc.

Hull, C.L. and L. Cawthen. 2013. Bat fatalities at two wind farms in Tasmania, Australia: bat characteristics, and spatial and temporal patterns. New Zealand Journal of Zoology 40(1):5-15.

Huso, M.M.P. and D. Dalthrop. 2014. Accounting for unsearched areas in estimating wind turbine-caused fatality. Journal of Wildlife Management 78(2):347-358.

Huso, M.M.P. and D. Dalthrop. 2014. A comment on “Bats killed in large numbers at United States wind energy facilities”. BioScience 64(6):546-547.

James, R.D. 2002. Pickering Wind Turbine, Bird monitoring program in 2002. Report to Ontario Power Generation, December 2002.

Jameson, J.W. and C.K.R. Willis. 2012. Bat mortality at a wind power facility in central

Canada. Northwestern Naturalist 93:194-202.

*Jameson, J.W. and C.K.R. Willis. 2014. Activity of tree bats at anthropogenic tall structures: implications for mortality of bats at wind turbines. Animal Behaviour 97:145-152.

Johnson, G.D. and E. Arnett. 2004. A bibliography of bat interactions with wind turbines. Unpublished. 9 p.

Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shepherd and D.A. Shepherd. 2000. Avian Monitoring Studies at the Buffalo Ridge Wind Resource Area, Minnesota: Results of a 4-year study. Technical report prepared for Northern States Power Co., Minneapolis, MN. 212pp.

Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shepherd, D.A. Shepherd, and S.A. Sarappo. 2003. Mortality of bats at a large-scale wind power development at Buffalo Ridge, Minnesota. The American Midland Naturalist 150(2):332-342.

Johnson, G.D., W.P. Erickson, and J. White. 2003. Avian and bat mortality at the Klondike, Oregon Phase I Wind Plant. Technical report prepared for Northwestern Wind Power by WEST, Inc.

Johnson, G.D., M.K. Perlik, W.P. Erickson, and M.D. Strickland. 2004. Bat activity, composition, and collision mortality at large wind plant in Minnesota. Wildlife Society Bulletin 32(4):1278-1288.

Johnson, G.D., M.K. Perlik, W.P. Erickson, M.D. Strickland, D.A. Shepherd, and P. Sutherland, Jr. 2003. Bat interactions with wind turbines at the Buffalo Ridge, Minnesota Wind Resource Area: An assessment of bat activity, species composition, and collision mortality. Electric Power Research Institute, Palo Alto, California, and Xcel Energy, Minneapolis, Minnesota. EPRI report # 1009178.

Johnson, G.D. and M.D. Strickland. 2003. Biological assessment for the federally endangered Indiana bat (*Myotis sodalis*) and Virginia big-eared bat (*Corynorhinus townsendii virginianus*), NedPower Mount Storm Wind Project, Grant County, West Virginia. Unpublished report prepared by WEST, Inc. for NedPower Mount Storm, Chantilly, Virginia.

Johnson, G.D., D.P. Young, Jr., W.P. Erickson, M.D. Strickland, R.E. Good and P. Becker. 2000. Avian and bat mortality associated with the initial phase of the Foote Creek Rim Wind power Project, Carbon County, Wyoming: November 3, 1998 - October 31, 1999. Technical Report prepared for SeaWest Energy Corporation and Bureau of Land Management. 32pp.

Johnson, J.S., K.S. Watrous, G.J. Giumarro, T.S. Peterson, S.A. Boyden, and M.J. Lacki. 2011. Seasonal and geographic trends in acoustic detection of tree-roosting bats. Acta Chiropterologica 13(1):157-168.

Johnson, P.B. 1933. Accidents to bats. Journal of Mammalogy 14:156-157.

Keeley, B., S. Ugoretz, and D. Strickland. 2001. Bat ecology and wind turbine considerations. Proceedings of the National Avian-Wind Power Planning Meeting, 4:135-146. National Wind Coordinating Committee, Washington, D.C.

Kelm, D.H., J. Lenski, V. Kelm, U. Toelch, and F. Dziock. 2014. Seasonal bat activity in relation to distance to hedgerows in an agricultural landscape in central Europe and implications for wind energy development. 16(1):65-73.

Kerlinger, P., R. Curry, and R. Ryder. 2000. Ponnequin wind energy project avian studies, Weld County, Colorado: Summary of activities during 2000. Prepared for Public Service Company of Colorado, Denver, Colorado.

Kiefer, A., H. Merz, W. Rackow, H. Roer, and D. Schlegel. 1995. Bats as traffic casualties in Germany. Myotis 32-33:215-220.

*Kiesecker, J.M., J.S. Evans, J. Fargione, K. Doherty, K.R. Foresman, T.H. Kunz, D. Naugle, N.P. Nibbelink, and N.D. Niemuth. 2011. Win-win for wind and wildlife: a vision to facilitate sustainable development. PLoS One 6:4:e17566. Doi:10.1371/journal.pone.0017566.

Klug, B.J. and E.F. Baerwald. 2010. Incidence and management of live and injured bats at wind energy facilities. Journal of Wildlife Rehabilitation 30(2):11-16.

Koford, R., A. Jain, G. Zenner and A. Hancock. 2004. Avian mortality associated with the Top of Iowa Wind Farm: Progress Report, Calendar Year 2003. Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University, Ames, Iowa. 9pp.

Korner-Nievergelt, F., P. Korner-Nievergelt, O. Behr, I. Niermann, R. Brinkmann, and B. Hellriegel. 2011. A new method to determine bird and bat fatality at wind energy turbines from carcass searches. Wildlife Biology 17:350-363.

Korstian, J.M., A.M. Hale, V.J. Bennett, and D.A. Williams. 2013. Advances in sex determination in bats and its utility in wind-wildlife studies. Molecular Ecology 13:776-780.

Krenz, J.D., and B.R. McMillan. 2000. Final Report: Wind-turbine related bat mortality in southwestern Minnesota. Minnesota Department of Natural Resources, St. Paul.

*Kunz, T.H., E.B. Arnett, B.M. Cooper, W.P. Erickson, R.P. Larkin, T. Mabee, M.L. Morrison, M.D. Strickland, and J.M. Szewczak. 2007. Assessing impacts of wind-energy development on nocturnally active birds and bats: a guidance document. Journal of Wildlife Management 71(8):2449-2486.

*Kunz, T.H., E.B. Arnett, W.P. Erickson, A.R. Hoar, G.D. Johnson, R.P. Larkin, M.D. Strickland, R.W. Thresher, and M.D. Tuttle. 2007. Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. Frontiers in Ecology and the Environment 5(6):315-324.

Mabee, T.J., B.A. Cooper, and J.H. Plissner. 2004. A radar study of nocturnal bird migration at the proposed Mount Storm wind power development, West Virginia, Fall 2003. Unpublished report prepared by ABR, Inc. for WEST, Inc. and Nedpower.

*Mathews, F., M. Swindells, R. Goodhead, T.A. August, P. Hardman, D.M. Linton, D.J. Hosken. 2013. Effectiveness of search dogs compared with human observers in locating bat carcasses at wind-turbine sites: a blinded randomized trial. Wildlife Society Bulletin 37(1):34-40.

Millon, L., J.F. Julen, R. Julliard, and C. Kerbiriou. 2015. Bat activity in intensively farmed landscapes with wind turbines and offset measures. Ecological Engineering 75:250-257.

*Minderman, J., C.J. Pendlebury, J.W. Pearce-Higgins, and K.J. Park. 2012. Experimental evidence for the effect of small wind turbine proximity and operation on bird and bat activity. PLoS One 7(7):e41177. Doi:10.1371/journal.pone.0041177.

Nicholson, C.P. 2003. Buffalo Mountain Windfarm bird and bat mortality monitoring report: October 2001 - September 2002. Tennessee Valley Authority, Knoxville.

Nicholson, C.P. 2001. Buffalo Mountain Windfarm bird and bat mortality monitoring report: October 2000 - September 2001. Tennessee Valley Authority, Knoxville.

Orloff, S. and A. Flannery. 1992. Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County Wind Resource Areas, 1989-1991. Final report to Alameda, Costra Costa and Solano Counties and the California Energy Commission by Biosystems Analysis, Inc., Tiburon, CA.

Osborn, R.G., K.F. Higgins, C.D. Dieter, and R.E. Usgaard. 1996. Bat collisions with wind turbines in southwestern Minnesota. Bat Research News 37:105-108.

Pandion Systems, Inc. 2003. White paper on bats and wind turbines with reference to the Backbone Mountain site. Unpublished report prepared for Florida Power & Light, Juno Beach, Florida.

Péron, G., J.E. Hines, J.D. Nichols, W.L. Kendall, K.A. Peters, and D.S. Misrahi. 2013. Estimation of bird and bat mortality at wind-power farms with superpopulation models. Journal of Applied Ecology 50:902-911.

Peste, F., A. Paula, L.P. da Silva, J. Bernardino, P. Pereira, M. Mascarenhas, H. Costa, J. Vieira, C. Bastos, C. Fonseca, M.J.R. Pereira. 2015. How to mitigate impacts of wind farms on bats? A review of potential conservation measures in the European context. Environmental Impact Assessment Review 51:10-22.

Piorkowski, M.D. and T.J. O'Connell. 2010. Spatial pattern of summer bat mortality from collisions with wind turbines in mixed-grass prairie. American Midland Naturalist 164(2):260-269.

Poulton, V. and W. Erickson. 2010. Post-construction bat and bird fatality study Judith Gap Wind Farm Wheatland County, Montana. Final Report. Results from June-October 2009 study and comparison with 2006-2007 study. Western Ecosystems Technology, Inc. 2003 Central Avenue, Cheyenne, WY. 35 p.

Puzen, S.C. 2002. Bat interactions with wind turbines in northeastern Wisconsin. Wisconsin Public Service Commission, Madison, Wisconsin.

Redell D., E.B. Arnett, J.P. Hayes, M.M.P. Huso. 2006. Patterns of preconstruction bat activity determined using acoustic monitoring at a proposed wind facility in south-central Wisconsin. A final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA. http://www.batsandwind.org/pdf/precon_wi.pdf

Reynolds, D.S. 2006. Monitoring the potential impact of a wind development site on bats in the northeast. Journal of Wildlife Management 70(5):1219-1227.

*Rollins, K.E., D.K. Meyerholz, G.D. Johnson, A.P. Capparella, and S.S. Loew. 2012. A forensic investigation into the etiology of bat mortality at a wind farm: barotrauma or traumatic injury? Veterinary Pathology 49(2):362-371.

Rocioni, F., H. Rebelo, D. Russo, M.L. Carranza, M.D. Febbraro, and A. Loy. 2014. A modelling approach to infer the effects of

wind farms on landscape connectivity for bats. Landscape Ecology 29:891-903.

Rydell J., L. Bach, M. Dubourg-Savage, M. Green, L. Rodrigues, and A. Hedenström. 2010. Bat mortality at wind turbines in northwestern Europe. Acta Chiropterologica 12(2):261–274. doi:10.3161/150811010X537846

Rydell, J., L. Bach, M. Dubourg-Savage, M. Green, L. Rodrigues, and A. Hedenstrom. 2010. Mortality of bats at wind turbines links to nocturnal insect migration. European Journal of Wildlife Research 56:823-827.

Saunders, W.E. 1930. Bats in migration. Journal of Mammalogy 11:225.

Schmidt, E., A.J. Piaggio, C.E. Bock, and D.M. Armstrong. 2003. National Wind Technology Center site environmental assessment: bird and bat use and fatalities – Final report NREL/SR-500-32981, National Renewable Energy Laboratory, Golden, Colorado. 21pp.

*Schuster, E., L. Bulling, and J. Koppel. 2015. Consolidating the state of knowledge: a synoptical review of wind energy's wildlife effects. Environmental Management 56:300-331.

Sjollema, A.L., J.E. Gats, R.H. Hilderbrand, and J. Sherwell. 2014. Offshore activity of bats along the mid-Atlantic Coast. Northeastern Naturalist 21(2):154-163.

Smallwood, K.S. 2013. Comparing bird and bat fatality-rate estimates among North American wind-energy projects. Wildlife Society Bulletin 37(1):19-33.

Smallwood, K.S., D.A. Bell, S.A. Snyder, and J.E. Didonato. 2010. Novel scavenger removal trials increase wind turbine-caused avian fatality estimates. Journal of Wildlife Management 74(5):1089-1097.

Smallwood, K.S. and B. Karas. 2009. Avian and bat fatality rates at old-generation and repowered wind turbines in California. Journal of Wildlife Management 73(7):1062-1071.

Tennessee Valley Authority. 2002. Draft Environmental Assessment - 20-MW Windfarm and Associated Energy Storage Facility. Tennessee Valley Authority, Knoxville, Tennessee.

Terres, J.K. 1956. Migration records of the red bat, *Lasiurus borealis*. Journal of Mammalogy 37:442.

Thelander, C.G. and L. Rugge. 2000. Bird risk behaviors and fatalities at the Altamont Wind Resource Area. Pp. 5-14 *in* Proceedings of the National Avian-Wind Power Planning Meeting III. National Wind Coordinating Committee/RESOLVE. Washington, D.C.

Tuttle, M.D. 2004. Wind energy and the threat to bats. BATS 22(2):4-5.

U.S. Department of Energy. 2002. Draft Site-Wide Environmental Assessment of National Renewable Energy Laboratory's National Wind Technology Center. U.S. Department of Energy, Golden, Colorado.

Van Gelder, R.G. 1956. Echo-location failure in migratory bats. Transactions of the Kansas Academy of Science 59:220-222.

Villegas-Patraca, R., S. Macias-Sanchez, I. MacGregor-Fors, and C. Munoz-Robles. 2012. Scavenger removal: bird and bat carcass persistence in a tropical wind farm. Acta Oecologica 43:121-125.

Voigt, C.C., L.S. Lehnert, G. Petersons, F. Adorf, and L. Bach. 2015. Wildlife and renewable energy: German politics cross migratory bats. European Journal of Wildlife Research 61:213-219.

*Voigt, C.C., A.G. Popa-Lisseanu, I. Niermann, and S. Kramer-Schadt. 2012. The catchment area of wind farms for European bats: a plea for international regulations. Biological Conservation 153:80-86.

*Weller, T.J. and J.A. Baldwin. 2012. Using echolocation monitoring to model bat occupancy and inform mitigations at wind energy facilities. Journal of Wildlife Management 76(3):619-631.

Williams, W. 2004. When blade meets bat: Unexpected bat kills threaten future wind farms. Scientific American. February 2004.

Williams, W. 2003. Alarming evidence of bat kills in eastern U.S. Windpower Monthly 19: 21-23.

Winhold, L., A. Kurta, and R. Foster. 2008. Long-term change in an assemblage of North American bats: are eastern red bats declining? Acta Chiropterologica 10(2):359-366.

Wisely, A.N. 1978. Bat dies on barbed wire fence. Blue Jay 36:53.

Wolbert, S.J., A.S. Zellner, H.P. Whidden. 2014. Bat activity, insect biomass, and temperature along an elevational gradient. Northeastern Naturalist 21(1):72-85.

Young, D.P., Jr., W.P. Erickson, R.E. Good, M.D. Strickland, and G.D. Johnson. 2003. Avian and bat mortality associated with the initial phase of the Foote Creek Rim wind power project, Carbon County, Wyoming: November 1998 – June 2002. Tech. Rept. prepared for SeaWest Energy Corporation and Bureau of Land Management.

Young, D.P., Jr., W.P. Erickson, M.D. Strickland, and R.E. Good. 2002. Comparison of avian effects from UV light reflective paint applied to wind turbines: Foote Creek Rim Wind Plant, Carbon County, Wyoming. National Renewable Energy Laboratory, Golden, Colorado.

## Appendix B

### Bat Pass Temperatures Summarized by Species and Month[1]

#### Water Treatment Ponds

| Species[2] | Year | Month | Bat Pass Temp C Avg (SD) N | Bat Pass Min Temp C | Bat Pass Max Temp C |
|---|---|---|---|---|---|
| EPFU | 2011 | 9 | 25.9 (2) 43 | 19.8 | 27.4 |
| EPFU | 2011 | 10 | 22.5 (3.2) 125 | 9.5 | 26.2 |
| EPFU | 2011 | 11 | 9.3 (2.7) 61 | 4.7 | 14 |
| EPFU | 2011 | 12 | 6.5 (2.1) 7 | 4.6 | 10.3 |
| EPFU | 2012 | 1 | 7.5 (0) 2 | 7.5 | 7.5 |
| EPFU | 2012 | 2 | 5 (0.4) 6 | 4.7 | 5.5 |
| EPFU | 2012 | 3 | 10.8 (3.3) 11 | 3.7 | 16.1 |
| EPFU | 2012 | 4 | 16.4 (4.1) 15 | 10.7 | 22.4 |
| EPFU | 2012 | 6 | 20.5 (3.1) 190 | 14.1 | 27.2 |
| EPFU | 2012 | 7 | 24 (3.1) 600 | 15.3 | 29.7 |
| EPFU | 2012 | 8 | 21.5 (3.9) 393 | 6.9 | 30 |
| EPFU | 2012 | 9 | 17.5 (3.1) 278 | 8.4 | 25.9 |
| EPFU | 2012 | 10 | 11.7 (0) 2 | 11.7 | 11.7 |
| EPFU | 2012 | 11 | 9.4 (2) 17 | 3.6 | 13 |
| EPFU | 2012 | 12 | 3.6 (0) 2 | 3.6 | 3.6 |
| EPFU | 2013 | 1 | 3.4 (0.4) 5 | 3.1 | 4.1 |
| EPFU | 2013 | 3 | 9.1 (0.8) 6 | 8.7 | 10.7 |
| EPFU | 2013 | 4 | 13.7 (2.4) 96 | 5.2 | 17.6 |
| EPFU | 2013 | 5 | 15.7 (2.6) 269 | 9.8 | 22.9 |
| EPFU | 2013 | 6 | 16.8 (0.7) 2 | 16.3 | 17.3 |
| EPFU | 2013 | 8 | 25.7 ([3]) 1 | 25.7 | 25.7 |
| EPFU | 2013 | 9 | 26.4 (1.6) 2 | 25.2 | 27.5 |
| EPFU | 2013 | 10 | 15 ([3]) 1 | 15 | 15 |
| EPFU | 2014 | 4 | 11.9 (0.1) 2 | 11.8 | 12 |
| EPFU | 2014 | 5 | 15.9 (4.4) 5 | 8.2 | 18.9 |
| EPFU | 2014 | 6 | 17.8 (2.2) 43 | 13.8 | 21.7 |
| EPFU | 2014 | 7 | 21.1 (3.3) 865 | 15 | 29.3 |
| EPFU | 2014 | 8 | 22.5 (1.4) 69 | 20.6 | 26 |
| EUMA | 2012 | 6 | 15 (1.8) 2 | 13.8 | 16.3 |
| EUMA | 2012 | 7 | 26.2 (1.8) 4 | 23.9 | 28.4 |
| EUMA | 2014 | 7 | 22.9 (3) 4 | 20.3 | 25.5 |
| EUMA | 2014 | 8 | 23.2 ([3]) 1 | 23.2 | 23.2 |
| LACI | 2011 | 10 | 25.9 (0) 2 | 25.9 | 25.9 |
| LACI | 2012 | 3 | 17.3 ([3]) 1 | 17.3 | 17.3 |

| | | | | | |
|---|---|---|---|---|---|
| LACI | 2012 | 6 | 18.1 (4.1) 32 | 11.7 | 27.2 |
| LACI | 2012 | 7 | 23.2 (3.2) 111 | 16.8 | 30.2 |
| LACI | 2012 | 8 | 18.8 (4.5) 33 | 8.7 | 28 |
| LACI | 2012 | 9 | 16.7 (3.4) 2 | 14.3 | 19.1 |
| LACI | 2012 | 10 | 14.3 ([3]) 1 | 14.3 | 14.3 |
| LACI | 2013 | 5 | 17.8 (0) 2 | 17.8 | 17.8 |
| LACI | 2013 | 8 | 22.2 (2.2) 3 | 19.6 | 23.7 |
| LACI | 2014 | 6 | 17.8 (2.5) 18 | 12.8 | 21.4 |
| LACI | 2014 | 7 | 22.5 (2.8) 244 | 15.3 | 29.3 |
| LACI | 2014 | 8 | 22.8 (1.1) 34 | 20.8 | 24.7 |
| LANO | 2011 | 9 | 24.1 (3.9) 9 | 18.6 | 27.4 |
| LANO | 2011 | 10 | 21.7 (3.2) 106 | 9.5 | 27.9 |
| LANO | 2011 | 11 | 9.6 (1.6) 43 | 4.7 | 11.8 |
| LANO | 2011 | 12 | 7.7 (2.1) 5 | 4.7 | 10.3 |
| LANO | 2012 | 1 | 8.4 ([3]) 1 | 8.4 | 8.4 |
| LANO | 2012 | 4 | 19.8 (2.2) 9 | 14.6 | 21.6 |
| LANO | 2012 | 6 | 19.3 (3.6) 179 | 10.3 | 27.2 |
| LANO | 2012 | 7 | 23.5 (3.1) 339 | 15.6 | 29.3 |
| LANO | 2012 | 8 | 21 (3.9) 161 | 10.5 | 28.2 |
| LANO | 2012 | 9 | 16.2 (3) 107 | 8.4 | 25.5 |
| LANO | 2012 | 10 | 19.3 ([3]) 1 | 19.3 | 19.3 |
| LANO | 2013 | 3 | 9.8 ([3]) 1 | 9.8 | 9.8 |
| LANO | 2013 | 4 | 13.9 (1.3) 35 | 10.7 | 17.1 |
| LANO | 2013 | 5 | 13.6 (2.9) 81 | 10.2 | 17.8 |
| LANO | 2013 | 6 | 17 (0.4) 4 | 16.6 | 17.4 |
| LANO | 2013 | 8 | 24.1 (2.8) 27 | 15.5 | 27.5 |
| LANO | 2013 | 9 | 22.7 (3.6) 14 | 18.4 | 29.5 |
| LANO | 2014 | 5 | 9 ([3]) 1 | 9 | 9 |
| LANO | 2014 | 6 | 16.2 (2.4) 181 | 10.3 | 21.7 |
| LANO | 2014 | 7 | 21.2 (3.4) 1507 | 14.8 | 29.3 |
| LANO | 2014 | 8 | 22.5 (1.5) 119 | 20.6 | 26.5 |
| MYCI | 2011 | 9 | 23.2 (3.5) 19 | 18.9 | 27.5 |
| MYCI | 2011 | 10 | 24.9 (0.7) 7 | 24.4 | 26.4 |
| MYCI | 2011 | 11 | 9.3 (1.9) 3 | 7.2 | 10.5 |
| MYCI | 2012 | 4 | 13.9 (4.1) 6 | 10.8 | 19.8 |
| MYCI | 2012 | 6 | 19.7 (2.4) 114 | 13.2 | 27.4 |
| MYCI | 2012 | 7 | 23.1 (3.1) 374 | 16.6 | 30.2 |
| MYCI | 2012 | 8 | 20.8 (3.4) 1810 | 10.8 | 30.2 |
| MYCI | 2012 | 9 | 16.8 (2.9) 537 | 8.5 | 25.9 |
| MYCI | 2013 | 1 | 1.7 (0) 4 | 1.7 | 1.7 |
| MYCI | 2013 | 4 | 11.2 (2.9) 4 | 9.7 | 15.6 |
| MYCI | 2013 | 5 | 15.7 (2.5) 72 | 10.3 | 22.9 |
| MYCI | 2013 | 6 | 17.4 (1.3) 4 | 16.1 | 18.9 |

| | | | | | |
|---|---|---|---|---|---|
| MYCI | 2013 | 8 | 21.8 (2) 8 | 19.3 | 24.2 |
| MYCI | 2014 | 4 | 10.2 ([3]) 1 | 10.2 | 10.2 |
| MYCI | 2014 | 5 | 13.3 (1.1) 2 | 12.5 | 14.1 |
| MYCI | 2014 | 6 | 16.8 (1.9) 19 | 14.5 | 20.3 |
| MYCI | 2014 | 7 | 21.5 (3.3) 199 | 15.5 | 29.3 |
| MYCI | 2014 | 8 | 22.4 (1.6) 35 | 20.8 | 26 |
| MYEV | 2011 | 9 | 15.4 (4.2) 8 | 11.7 | 25.4 |
| MYEV | 2011 | 10 | 24.9 ([3]) 1 | 24.9 | 24.9 |
| MYEV | 2012 | 6 | 19.4 (3.4) 37 | 13.5 | 27 |
| MYEV | 2012 | 7 | 23.8 (2.7) 177 | 16.6 | 28.5 |
| MYEV | 2012 | 8 | 20 (4.6) 63 | 8.7 | 28 |
| MYEV | 2012 | 9 | 16.2 (2.7) 196 | 8.4 | 25.5 |
| MYEV | 2013 | 5 | 12.7 (0.9) 3 | 11.7 | 13.5 |
| MYEV | 2013 | 6 | 15 ([3]) 1 | 15 | 15 |
| MYEV | 2013 | 8 | 23.7 ([3]) 1 | 23.7 | 23.7 |
| MYEV | 2013 | 9 | 24.2 (0.9) 5 | 23.4 | 25.2 |
| MYEV | 2014 | 5 | 14.9 (3.8) 2 | 12.2 | 17.6 |
| MYEV | 2014 | 6 | 17.2 (2) 16 | 14 | 20.4 |
| MYEV | 2014 | 7 | 20.9 (3.1) 141 | 15.5 | 29.5 |
| MYEV | 2014 | 8 | 22.8 (1.9) 12 | 20.6 | 26 |
| MYLU | 2011 | 9 | 22.4 (3.5) 17 | 19.6 | 27.7 |
| MYLU | 2011 | 10 | 22.5 (4.6) 4 | 17.8 | 26.4 |
| MYLU | 2012 | 4 | 20.4 (1.4) 3 | 18.9 | 21.6 |
| MYLU | 2012 | 6 | 19.5 (3.4) 186 | 10.5 | 27.4 |
| MYLU | 2012 | 7 | 22.5 (3.7) 423 | 15.8 | 30.2 |
| MYLU | 2012 | 8 | 21.5 (3.7) 805 | 7 | 30.2 |
| MYLU | 2012 | 9 | 17 (3.1) 1746 | 8.5 | 26 |
| MYLU | 2013 | 4 | 14 (2.6) 8 | 9.2 | 16.5 |
| MYLU | 2013 | 5 | 15.3 (3) 97 | 3.1 | 23.6 |
| MYLU | 2013 | 6 | 16.1 (2) 20 | 10 | 18.9 |
| MYLU | 2013 | 8 | 22.1 (2.5) 159 | 15 | 28.9 |
| MYLU | 2013 | 9 | 22.8 (2) 122 | 14.5 | 27.7 |
| MYLU | 2014 | 4 | 8 ([3]) 1 | 8 | 8 |
| MYLU | 2014 | 5 | 16.5 (4.4) 45 | 9 | 23.2 |
| MYLU | 2014 | 6 | 16.9 (2.8) 55 | 10.5 | 21.1 |
| MYLU | 2014 | 7 | 23.3 (3.2) 183 | 15.8 | 29.5 |
| MYLU | 2014 | 8 | 22.5 (1.6) 79 | 20.6 | 26.7 |

**Wind Turbine**

| | | | | | |
|---|---|---|---|---|---|
| EPFU | 2013 | 7 | 16.4 (1.1) 2 | 15.6 | 17.1 |
| EPFU | 2013 | 8 | 15.5 (0) 2 | 15.5 | 15.5 |
| EPFU | 2014 | 7 | 20.9 (2.9) 14 | 16.3 | 26.5 |
| EPFU | 2014 | 8 | 20 (2.7) 8 | 16.1 | 22.9 |
| EPFU | 2014 | 9 | 21.4 ([3]) 1 | 21.4 | 21.4 |
| LACI | 2014 | 6 | 14.7 (1.4) 10 | 12 | 16.1 |
| LACI | 2014 | 7 | 19.5 (3.4) 23 | 13.5 | 24.6 |
| LACI | 2014 | 8 | 12.8 (1.8) 2 | 11.5 | 14 |
| LACI | 2014 | 9 | 7.4 ([3]) 1 | 7.4 | 7.4 |
| LANO | 2014 | 6 | 15.4 (4.3) 5 | 8.4 | 18.9 |
| LANO | 2014 | 7 | 20 (3.6) 10 | 15.1 | 26.2 |
| LANO | 2014 | 8 | 17.7 (3.5) 9 | 11.3 | 22.7 |
| LANO | 2014 | 9 | 17.2 (2.2) 5 | 13.6 | 18.9 |
| MYCI | 2013 | 7 | 19.8 (1.2) 2 | 18.9 | 20.6 |
| MYCI | 2013 | 8 | 23.9 ([3]) 1 | 23.9 | 23.9 |
| MYCI | 2014 | 6 | 15.8 ([3]) 1 | 15.8 | 15.8 |
| MYCI | 2014 | 7 | 19.9 (3.5) 16 | 14.1 | 25.5 |
| MYCI | 2014 | 8 | 20.1 (2.9) 6 | 16.1 | 23.2 |
| MYCI | 2014 | 9 | 6.7 ([3]) 1 | 6.7 | 6.7 |
| MYEV | 2013 | 7 | 13.6 ([3]) 1 | 13.6 | 13.6 |
| MYEV | 2013 | 8 | 21.9 ([3]) 1 | 21.9 | 21.9 |
| MYEV | 2014 | 7 | 22.4 (2.9) 4 | 18.3 | 24.6 |
| MYEV | 2014 | 8 | 18.4 (2.2) 3 | 16 | 20.4 |
| MYEV | 2014 | 9 | 16.4 (1.3) 3 | 15 | 17.3 |
| MYLU | 2013 | 5 | 16.6 ([3]) 1 | 16.6 | 16.6 |
| MYLU | 2013 | 6 | 16.8 (1.5) 2 | 15.8 | 17.9 |
| MYLU | 2013 | 7 | 18 (2.9) 2 | 16 | 20.1 |
| MYLU | 2013 | 8 | 19.5 (4.5) 5 | 12.2 | 23.9 |
| MYLU | 2013 | 9 | 22.2 (1.9) 5 | 19.4 | 24.1 |
| MYLU | 2014 | 6 | 14.3 (1.9) 7 | 12.3 | 17.9 |
| MYLU | 2014 | 7 | 20.7 (3.8) 25 | 14.3 | 26.7 |
| MYLU | 2014 | 8 | 19 (3.5) 34 | 12.5 | 25.9 |
| MYLU | 2014 | 9 | 15.1 (4) 36 | 3.1 | 21.4 |

[1] Only records auto-identified to species are included and only species with auto identification accuracies from Sonobat 3.0 evaluated through manual review as greater than 50% are included.
[2] Species codes are the first two letters of the genus and species names.
[3] Cannot calculate standard deviation with a single value.